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CONTENTS.

	PAGE.
The New Session, 1933-34	301
Bamboo Art Silk from India	302
Experimentation and applied statistics for the practical Agriculturist	303
Plant Breeding in Southern Nigeria	312
Papaw Selection	317
The Classification of Groundnut Varieties	318
Papaw Root and Collar-Rot	328
The Relationship between Degree Brix (Hydrometer) and Degree Brix (Refractometer) in Final Molasses II	330
Chemical Notes	331
Trend of the Markets	332

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE, TRINIDAD, B.W.I.

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TROPICAL AGRICULTURE is published monthly at the Imperial College of Tropical Agriculture, St. Augustine, Trinidad, West Indies. Advertisement and subscription rates can be obtained at the College from the Editor, or from the Secretary of the College, 14, Trinity Square, London, E.C. 3, England. The Editor will be glad to consider authoritative articles for publication. It is understood that opinions expressed or recommendations made in signed articles or in articles of which the source is named are those of the author and do not necessarily represent the policy or opinion of the College Authorities. Increasing numbers of inquiries are being received from the various parts of the tropics which can be answered only by persons possessed of an intimate knowledge of local conditions. Enquirers should first satisfy themselves that their local Department of Agriculture is not able to supply them with the desired information before communicating with us. Correspondence which will be replied to is invited on all other matters pertaining to tropical agriculture, science and development.

THE NEW SESSION, 1933-34.

It will not be denied that we live in the midst of rapidly changing conditions. With the abolition of the Empire Marketing Board from which a considerable portion of the revenue of the Imperial College of Tropical Agriculture has been derived, the difficulties of the present financial situation have been brought nearer to us than in the past. Nevertheless, we are assured that the College will be one of the first Institutions to be considered by the Imperial Government in their new schemes for Colonial development. Because of this assurance we may, with safety, anticipate that the scientific and teaching activities of this Institution will continue uninterrupted.

The opening of the new session is accompanied by a number of changes of general interest. Reference must first be made to the retirement of Professor Ballou. This officer, who held the joint post of Commissioner of Agriculture and of Professor of Entomology for the past twelve years, will be greatly missed, not only by ourselves, but also by the West Indies, whose interests he always has had at heart during the course of his distinguished career. We take this opportunity of wishing him many happy years of retirement. The Assistant Commissioner has succeeded him, while a new post, described as that of Assistant to the Commissioner, has been created and filled by the Lecturer in Mycology. The Chair in Entomology has been left vacant temporarily, a Senior Lecturer being now in charge. Also, for the first time in the history of the College an interchange of officers has taken place and while the Carnegie Professor of Economics is travelling in an advisory capacity in the Gold Coast and Nigeria, a Senior Officer of the Gold Coast Department of Agriculture is deputising for him here. We hope that this may prepare the way for further exchanges of officers as, where feasible, such a system should prove of value both to the College and the Colony concerned by making for a wider outlook on tropical agriculture. The vacancy in the Mycology Department has been filled by one of last year's Post-Graduate students. This completes the record of Staff changes.

The Principal, in addition to his present duties, has been made Controller of the Trinidad Cotton Research Station. Also, as a result of a Conference

convened at the Colonial Office last summer it was decided that, as a general principle, research officers working in the Caribbean area will in future be attached to the College for administrative purposes. This means that these officers will not only make use of the College Library and research facilities but that they will also be available for consultative purposes. The advisory side of the College activities has thus been strengthened to the advantage of the area which it is at present serving.

In spite of the difficult times which are being experienced everywhere it is satisfactory to record that the number of students attending the Diploma course has been maintained. Of these students, nineteen come from the British West Indies, two from Colombia, one from Martinique and one from England. In view of the lack of vacancies in the Colonial Agricultural Services, the anticipated reduction in the number of Colonial scholars has been realised. There is little doubt, however, that as soon as conditions improve the demand for properly trained officers will again arise, since many of the Departments of Agriculture are at present understaffed, a state of affairs which obviously cannot continue without impairing general efficiency. In this connection, the Commonwealth of Australia, recognising the need for properly qualified officers to supervise the agricultural interests of their tropical and mandated territories, have this year sent for the first time an agricultural officer from New Guinea for training at the College. It is hoped that under this scheme we shall in future welcome other Australian Post-Graduates in Trinidad. Similarly, the Ceylon Government has devised a scheme by which their agricultural officers will be allowed to attend refresher courses here. Two Indian Governments, those of the Madras Presidency and of the United Provinces have also approached the College with a view to establishing scholarship schemes for students desiring to specialise in Sugar Technology; the first of these students will be arriving shortly. This general tendency whereby students from all parts of the Empire are being encouraged to attend Post-Graduate courses at the College is a hopeful development. It offers considerable possibilities and will be watched with interest.

Turning to research, steady progress has been made during the past session and some of the results of the useful work done by the Low Temperature Station, the Sugar-Cane Investigation Committee and the Mycology Department have been published from time to time in these columns. The work of the Cacao Research Officers has been dealt with in two comprehensive Reports which have generally been well received while the College Department of Chemistry has continued its studies of West Indian soils by carrying out soil surveys in Grenada, Antigua and Jamaica. The information collected has appeared in three separate Reports. The coming session will see the publication of various Reports which are at present in the press.

Another recent development has been the erection of a plant quarantine station which will be expected to serve the needs of the British Caribbean area.

When consideration is given to the broader aspects of the effect of the world economic crisis on agricultural research it must be recognised that there is at present a certain body of public opinion opposed to the continuation of research at a time when many producers are selling at a loss. One answer to this is supplied by Sir John Russell in a recent Report from the Rothamsted Experimental Station: "Scientific investigations in agriculture are primarily for the purpose of obtaining information and this will always be needed so long as farming continues. It is in times of difficulty that exact information about soils, crops and animals is most valuable to farmers, for it enables them rapidly to alter their methods in accordance with the rapidly changing economic conditions". These words obviously apply just as much to the planter in the tropics as they do to the British farmer. The producer can do little unfortunately to alleviate present conditions as the future of agriculture will depend to a large extent on the solution of very difficult problems such as, for instance, the relaxation of international trade barriers, unemployment, disarmament and war debts, all of which are obviously beyond his control. It is only to be hoped that the various attempts which are being made to deal with these problems will eventually prove successful. In the meantime the fruits of research are there and can always be had for the asking by those who desire to make full use of recent discoveries.

BAMBOO ART SILK FROM INDIA.

Experiments are being made at the Forest Research Institute at Dehra Dun to produce artificial silk from bamboo pulp, and it is understood that partial success has already been attained. Cellulose was prepared from Ochlandra travancoria (*eta* bamboo) conforming to the specifications demanded by the artificial silk industry, but the preparation fell short to some extent of the necessary requirements. The maximum percentage of α-cellulose, which is the most important constituent in cellulose for the manufacture of artificial silk, is only 89-90 in bamboo pulp; the percentage of ash in bamboo pulp is also high, *i.e.*, 0.3 per cent. as against 0.1 to 0.2 per cent., the maximum required in cellulose for art silk.

Further experiments are in progress, from which it is confidently hoped that it will be possible to attain the necessary high percentage of α-cellulose and also to reduce the ash percentage. The successful solution of the problem would encourage the establishment of a new and important industry in India and provide an additional outlet for the utilization of bamboos.—(*Chem. and Ind.* Vol. LI, No. 42, p. 864.)

EXPERIMENTATION AND APPLIED STATISTICS FOR THE PRACTICAL AGRICULTURIST.—*Continued.*

BY

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IX. The Latin Square.

THIS is a common and useful modification of the randomised block lay-out. In the Latin Square, the number of different treatments must be made equal to the number of replications used, which means that the square of either gives the total number of plots in the experiment. The plots are laid out in a single large block so as to give the same number in line counting either across or along the field, *i.e.*, the number of rows is equal to the number of columns. The shape of this block will normally be square or rectangular, depending on the shape of the individual plots. The term "Square" applied to this field arrangement is, therefore, used only in the conventional sense. While the plot dimensions can be made to suit the particular site, very long narrow types of plot should be avoided, as they tend to neutralise the value of the Latin Square arrangement. Where rectangular plots are used, the long axis of all the plots should be along the same compass direction. Each treatment occurs on one plot, and one plot only, in each row and in each column, but the allocation of the treatments within the rows and columns is otherwise at random.

While a suitable field arrangement for a Latin Square of any given size can be obtained from the Statistical Office at Rothamsted, it is a fairly simple matter to draw one up for any proposed experiment. One way of doing this is to allot the treatments to the plots in the first row and first column in the Square by drawing, at random from a box, tickets labelled with the different treatments. The remaining plots in the "Square" should then be filled in with their respective treatments in any way that will maintain the necessary proviso that every treatment should occur once in each row and each column. This will entail some readjustment of treatments within the remaining blank spaces. In order to obtain complete randomisation, it is best to finish the process by a chance reshuffling of the rows and columns. Thus, a 5 × 5 Latin Square for Treatments A, B, C, D, E, might be made as follows :—

1st Step.

B	A	C	D	E
C				
E				
D				
A				

2nd Step. (Filling Up Blanks.)

B	A	C	D	E
C	D	E	B	A
E	C	B	A	D
D	B	A	E	C
A	E	D	C	B

3rd Step. (Reshuffling Rows.)

E	C	B	A	D
A	E	D	C	B
D	B	A	E	C
B	A	C	D	E
C	D	E	B	A

4th Step. (Reshuffling Columns to give Final Arrangement.)

C	A	D	B	E
E	C	B	D	A
B	E	C	A	D
A	D	E	C	B
D	B	A	E	C

Any Latin Square could be analysed as a randomised block lay-out in which the plots in each column or in each row represent the individual blocks. In the statistical analysis of the Latin Square as such, both the column and the row groupings are used to calculate the S.S. due to soil differences, and this eliminates from the estimation of error variance the fertility differences in two directions at right angles to one another.

Example VII.

A 3 × 3 Latin Square in which three Varieties A, B, and C were under test gave the following yields in lb. per $\frac{1}{20}$th acre plot.

TABLE VIIA.—YIELD IN LB. PER PLOT (THE PLOT TREATMENT, *i.e.*, VARIETY SHOWN IN HEAVY TYPE).

	Rows.			Totals of Rows	Totals of Treatments.
Columns. ↓	**B** 5	**A** 3	**C** 4	12	A=18
	A 10	**C** 5	**B** 3	18	B=12
	C 6	**B** 4	**A** 5	15	C=15
Totals of Columns	21	12	12	Grand Total=45.	

TABLE VIIB.—TABLE OF SQUARES OF :—

Plot Yields.	Row Totals.	Column Totals.	Treatment Totals.
25 100 36	144	441	324
9 25 16	324	144	144
16 9 25	225	144	225
261	693	729	693

Correction Factor $= \frac{45^2}{9} = 225.$

TABLE VIIC.—ANALYSIS OF VARIANCE.

Due to	Sum of Squares.	Degrees of Freedom.	Variance.
Total ..	261 − 225 = 36	8	—
Rows ..	$\frac{693}{3} - 225 = 6$	2	3
Columns ..	$\frac{729}{3} - 225 = 18$	2	9
Treatments	$\frac{693}{3} - 225 = 6$	2	3
Error ..	36 − (6+18+6) = 6	8 − (2+2+2) = 2	3

The variety or treatment totals can now be compared, as previously described, by the *z* test and by the calculation of the significant difference between treatment totals. In the above example, it is obvious that, as the treatment variance is no greater than the error variance, the difference between treatment totals is a chance one and that in consequence, as far as the quoted data show, varieties A, B, and C are all equally good.

Let x = Any one plot yield.

n = The number of treatments or the number of plots in any row or any column.

T = The Grand Total of all plot yields.

T_t = The total yield of the n plots of any one treatment.

T_r = The total yield of the n plots in any one row.

T_c = The total yield of the n plots in any one column.

Then, by the variable-squared method,

The Total S.S. $= \Sigma x^2 - \frac{T^2}{n^2}$ having $n^2 - 1$ degrees of freedom.

The Treatment S.S. $= \frac{\Sigma T_t^2}{n} - \frac{T^2}{n^2}$ having $n - 1$ degrees of freedom.

The Row S.S. $= \frac{\Sigma T_r^2}{n} - \frac{T^2}{n^2}$ having $n - 1$ degrees of freedom.

The Column S.S. $= \frac{\Sigma T_c^2}{n} - \frac{T^2}{n^2}$ having $n - 1$ degrees of freedom.

The Error S.S. = Total S.S. − (Treatment S.S. + Row S.S. + Column S.S.) having $(n-1)(n-2)$ degrees of freedom.

In such a small scale experiment made up of a total of only nine plots and three replications of each treatment, it rarely happens that the differences between treatments are sufficiently large to allow statistical proof of their significance. Where only three treatments are being tested, the Latin Square lay-out limits the number of replications to three. Under such circumstances, it is better to lay down two or even three Latin Squares, in order to obtain a suitable number of replications and an error variance based on a reasonably large number of degrees of freedom. Even with a 4 x 4 Square, two squares are much more likely to give conclusive results than a single one. In replicating squares in this fashion, the randomisation of the treatments between the rows and columns should be done separately for each square.

Example VIII.

Yield Data for a second 3 × 3 Latin Square in which the same three Varieties (A, B and C) as in Example VII are under test.

SQUARE II.

	Rows.			Row Totals.	Treatment Totals.
Columns	**C** 12	**B** 5	**A** 7	24	A = 22
	B 3	**A** 9	**C** 15	27	B = 13
	A 6	**C** 19	**B** 5	30	C = 46
Column Totals ..	21	33	27	Grand Total = 81	

SQUARE I.—(FROM EXAMPLE VII.)

	Rows.			Row Totals.	Treatment Totals.
Columns.	B 5	A 3	C 4	12	A = 18
	A 10	C 5	B 3	18	B = 12
	C 6	B 4	A 5	15	C = 15
Column Totals ..	21	12	12	Grand Total = 45	

There are now 18 plots in all, six of each variety, arranged in two separate Latin Squares and the method of analysis is consequently, rather more complex. There is a striking difference between the grand totals of the individual squares, showing that the second square is located in a more favourable environment—probably more fertile soil—than the first. With this lay-out, it is possible to eliminate from the total S.S. for all plots in the experiment, the S.S. due to fertility differences between rows and columns in the separate squares, and also the S.S. due to fertility differences between the two squares. Using the variable-squared method, the correction factor is $\frac{(45+81)^2}{18}=882$. The total S.S. is the sum of squares of the individual plot yields less the correction factor, *i.e.*, $\Sigma x^2-882=334$, having 17 degrees of freedom. The S.S. due to rows for the experiment is the sum of the S.S. rows calculated for each square separately: the degrees of freedom will also be the sum of the respective degrees of freedom: similarly with columns.

Therefore S.S. Rows $=\left(\frac{24^2+27^2+30^2}{3}-\frac{81^2}{9}\right)+\left(\frac{12^2+18^2+15^2}{3}-\frac{45^2}{9}\right)=$ $6+6=12$, having 4 degrees of freedom.

Similarly S.S. Columns $=18+24=42$, having 4 degrees of freedom.

The S.S. due to Squares $=\frac{45^2+81^2}{9}-882=72$.

As there are in this experiment only two squares, this S.S. has one degree of freedom.

A clearer idea of the exact relationship that exists between the S.S. rows and columns and squares, may be obtained from the following explanation. If the experiment had been arranged on a randomised block lay-out with six blocks (*i.e.* rows or columns) of three plots each, the S.S. blocks could be calculated in the usual way. Then the S.S. rows as calculated above = the S.S. blocks—S.S. Squares.

Thus, S.S. Rows =

$$\left\{\frac{24^2+27^2+30^2+12^2+18^2+15^2}{3}\right\}-882-72=12.$$

And similarly with the S.S. Columns.

Before the S.S. due to treatments for the double Latin Square lay-out can be estimated, it is necessary to draw up a further table, as follows :—

Variety.	Square I.	Square II.	Total of Varieties.
A	18	22	40
B	12	13	25
C	15	46	61
Total of Squares ..	45	81	Grand Total = 126

In this experiment the treatment really consists of a combination of variety and site, i.e. Variety and Latin Square.

The total treatment effect S.S. is

$$\frac{18^2+12^2+15^2+22^2+13^2+46^2}{3}-882$$

$=272$, having 5 degrees of freedom.

This total treatment effect is made up of three distinct factors, the S.S. Squares (as already calculated) the S.S. Variety, and a residual S.S. which is termed the Interaction between Squares and Variety. The three varieties may not respond in the same way to the different conditions in the two squares. For example, the better environment in the second square has increased the yield of A, 21 per cent., of B, 8 per cent., but of C, 200 per cent. This residual S.S. or interaction represents the differential response between variety and square.

The S.S. Variety $=\frac{40^2+25^2+61^2}{6}-882$

$=109$ with 2 degrees of freedom.

The S.S. Interaction (Variety × Square) = Total Treatment Effect S.S. − (S.S. Square + S.S. Variety)

$=272-(72+109)=91.$

The Interaction has the balance of the degrees of freedom, *i.e.* $5 - (1 + 2) = 2$.

The complete Analysis of Variance is :—

Due to	Sum of Squares.	Degrees of Freedom.	Variance.	$\frac{1}{2}$ Log$_e$ (Nat. Log.)
Total ..	334	17	—	
S.S. Rows ..	12	4	3.0	
S.S. Columns	42	4	10.5	
S.S. Square	72	1	72.0	
S.S. Variety	109	2	54.5	1.9991
S.S. Interaction (Variety × Square) ..	91	2	45.5	
S.S. Error ..	334 − 326 = 8	17 − 13 = 4	2.0	.3466

The variance for variety is much greater than that for error, and the differences between variety yields are, therefore, significant. The calculated value of z is 1.6525 as compared with an observed value of .9690 (P=.05). The variety yields for a total of six plots are :—

A = 40 lb.
B = 25 lb.
C = 61 lb.

A difference between these totals greater than $\sqrt{2 \times 6 \times 2 \times 2.776}$, or 13.6 is significant. Variety C is better than A, and A is better than B.

The variety variance is not the only one that indicates significance. The variance for squares and for interaction also shows significance when compared with the error variance. This high variance for squares proves that there is a very marked difference in fertility between the two squares, and this is reflected in the yield data.

The significant interaction variance permits the use of the error variance to compare the relative yields of each variety in the separate squares in order to determine how the varieties respond to different environmental conditions. There are three plots of each variety in each square, so that a difference between such totals greater than $\sqrt{2 \times 3 \times 2 \times 2.776}$ or 9.58 is significant. Variety C gave a yield from the three plots on Square I of 15 lb. and on Square II of 46 lb. The difference of 26 lb. is decidedly significant. There is no significant difference when the yields of the other two varieties from the separate squares are compared. The final conclusion would be that some factor in Square II has favoured the production of high yields in Variety C but does not appear to have influenced the yields of the other two varieties. Where the difference is as striking as that quoted in this fictitious example, observations made during the growth of the crop will normally indicate the nature of the factor involved, such as soil conditions, immunity to certain fungal or insect pests, botanical characteristics, &c.

X.—Modifications of the Latin Square.

The following diagrams depict some optional field arrangements which permit a valid analysis of variance of the yield data. The statistical methods are fundamentally the same as those described for the randomised block or Latin Square lay-out. The Sums of Squares due to similar groups of plots, *e.g.*, Blocks, Rows, Columns, Sections, Treatments, &c., are subtracted from the total S.S. for all plots, leaving a residual S.S. and residual number of degrees of freedom on which the measure of significance depends.

A	D	C	B
B	C	D	A
C	B	A	D
D	A	B	C

The *Magic Square* in which every treatment occurs once in each row, once in each column, and once in each quarter.

B 2	A 1	C 3
A 3	C 2	B 1
C 1	B 3	A 2

The *Graeco-Latin Square* in which two separate types of treatment, *e.g.* variety and spacing—are superimposed on each plot. Each treatment type is arranged as a Latin Square, so that each row and each column contains the same total treatment. In addition all combinations of treatment types as A1, A2, A3, B1, B2, &c., are represented.

D F	C B	A E
E B	F A	C D
A C	E D	B F

In this arrangement, the treatments are arranged in blocks and columns so that each treatment occurs once in each block and once in each column. Where the treatments are numerous, this lay-out has most of the advantages of the Latin Square, yet avoids the necessity of the large number of plots associated with a Latin Square containing six or more treatments.

XI. Serial Experiments.

The conclusions from any one experiment are only true for the particular season and the particular soil conditions in which the test is carried out. It is essential to repeat any important experiment over a number of different years in order to ascertain whether the results hold good under different seasonal conditions. It is also advisable to vary the site from year to year, or, in any one year, to duplicate the experiment in different localities to test the general accuracy of the results for varying soil conditions.

The final recommendations should be based on the accumulated data of all the experiments, say over a three year period. There are various ways of arriving at such comprehensive conclusions. As the yield data from each year's experiment will normally be analysed as soon as the records

reach the laboratory, a simple method is to make a resumé of these individual results and use this accumulated evidence to assess the outstanding characteristics, +or −, of the different treatments. For example, if Variety A had shown itself in a variety test to be the best yielder in three years out of four, this could be taken as sufficient proof to designate it as a first class type. If, on the other hand, it had been excellent in two of the years, and below average in the other two, it would come into the second class range as being a doubtful yielder in certain seasons.

While this system of combining the results is perfectly practicable, it does not make the fullest possible use of the total data, and, in any case, more accurate methods of evaluating the accumulated data from a series of similar experiments are available. The yield data from all the experiments must first of all be collected into a single carefully constructed Table which is then analysed by the analysis of variance to determine the significance of all the interacting factors. The following concrete example illustrates in a general way how such an analysis would be effected.

In the experiment below there are two Varieties sown out in twelve randomised blocks making 24 plots in all. The arrangement is further complicated, or, as it is generally termed, confounded by the fact that the blocks and treatments are arranged in three groups according to the particular crop year. In estimating the error variance, it is necessary to subtract from the Total S.S. that portion attributable to the following factors :—

Block

Treatment.

Season.

Interaction of Treatment x Season.

Using the variable-squared method,

the correction factor is $\frac{192^2}{24} = 1536$.

In Table IXB in the calculation of the S.S. due to blocks, they have been treated as if they are all similar units. They differ in that they are arranged in groups of four in accordance with the year. The estimated S.S. due to blocks therefore includes the S.S. due to season.

The true S.S. for Blocks = 225 − 208 = 17.

This will have the balance of the degrees of freedom for blocks and seasons = 11 − 2 = 9.

Example IX.

Yield of Seed Cotton in lb. per $\frac{1}{100}$th acre plot from a trial of two varieties of cotton, A and B, for three experiments over a three-year period, a 2×4 randomised block lay-out and the same size of plot being maintained throughout.

TABLE IXA.—YIELD DATA IN LB. PER PLOT × 2*.

Year.	No. of Block.	Variety. A	Variety. B	Totals Across.
1	1	6	9	15
	2	7	8	15
	3	7	7	14
	4	4	8	12
Totals for 1st Year ..	.. ..	24	32	56
2	5	3	5	8
	6	5	4	9
	7	7	4	11
	8	5	7	12
Totals for 2nd Year ...	.. ..	20	20	40
3	9	10	16	26
	10	6	20	26
	11	8	15	23
	12	8	13	21
Totals for 3rd Year ..	.. ..	32	64	96
Total for 3-Year period ..	.. ..	76	116	192

* In these experiments, the yields were measured to the nearest ½ lb. In order to avoid having to work with decimal fractions in the statistical calculations, each plot yield has been multiplied by 2. The figures quoted are therefore half-pound units. In most statistical work, the preliminary elimination of decimal fractions by multiplying by 2 or 10 or 100, or x, depending on the particular data, is recommended as a means of reducing the chances of arithmetical error in calculations where squares and square roots are concerned. In formulating the final conclusions it is necessary to divide the various totals and standard errors, &c., by the same factor in order to revert to the original units.

TABLE IXB.—TABLE OF SQUARES.

Square of Plot Yields.	Blocks.		Treatments.		Seasons.		Combined Season × Treatment.	
	Totals.	Squares.	Totals.	Squares.	Totals.	Squares.	Totals.	Squares.
36								
49	15	225	76	5,776	56	3,136	24	576
49								
16	15	225	116	13,456	40	1,600	32	1,024
9								
25	14	196	—	—	96	9,216	20	400
49								
25	12	144	—	—	—	—	20	400
100								
36	8	64	—	—	—	—	32	1,024
64								
64	9	81	—	—	—	—	64	4,096
81								
64	11	121	—	—	—	—	—	—
49								
64	12	144	—	—	—	—	—	—
25								
16	26	676	—	—	—	—	—	—
16								
49	26	676	—	—	—	—	—	—
256								
400	23	529	—	—	—	—	—	—
225								
169	21	441	—	—	—	—	—	—
1,936		3,522		19,232		13,952		7,520
	Sums of Squares.							
1,936 − 1,536 = 400	$\frac{3522}{2^*} - 1,536 = 225$		$\frac{19232}{12^*} - 1,536 = 67$		$\frac{13952}{8^*} - 1,536 = 208$		$\frac{7520}{4^*} - 1,536 = 334$	

The true S.S. for blocks can be calculated directly if the S.S. blocks for each year's experiment is worked out separately. Thus S.S. Blocks for the three year period = S.S. Blocks Year I + S.S. Blocks, Year II + S.S. Blocks, Year III

= 3+5+9=17 } as
The Degrees of Freedom } given
= 3+3+3=9 } above.

The S.S. Interaction, Season × Treatment = S.S. Combined Season × Treatment − (S.S. Season + S.S. Treatment)
= 344 − (208+67) = 69 having
The Degrees of Freedom = 5 − (2 + 1) = 2.

Examination of the Variance Column Table IXc shows that the factor which has had most influence on the yields, is the season. This large effect of season is quite a common phenomenon in field experiments, and demonstrates the folly of basing general recommendations in regard to cultural treatment on the results of a single year's experimentation. Treatment and interaction variances also give definite significance when compared with that for error by means of the z test. The error variance can therefore be used to compare the treatment totals for the three-year period, and also for each year separately.

The Standard Error for a total of 12 plots = $\sqrt{4.3 \times 12}$.

TABLE IXC.

Due to	S.S.	Degrees of Freedom.	Variance.	$\frac{1}{2}$ Log$_e$ of Variance.	Calculated Value of z	Observed Value of z from Fisher's Tables.
Total	400	23	—	—	—	—
Blocks	17	9	1.9	.3209	.4084	.5862
Treatment	67	1	67.0	2.1023	1.3730	.8163
Season	208	2	104.0	2.3222	1.5929	.7242
Interaction, Season × Treatment	69	2	34.5	1.7705	1.0412	.7242
Error	39	9	4.3	.7293	—	—

* The number of plots represented in each of the totals that are squared in the above column.

A difference between such totals greater than $\sqrt{4.3 \times 12 \times 2 \times 2.262}$* or 23.0 is significant. Variety totals are :—

A = 76 half pound units } giving a difference of
B = 116 do. } 40 half pounds.

Over the three-year period therefore, Variety B has proved a distinctly better yielder than A.

The Standard Error for a total of 4 plots = $\sqrt{4.3 \times 4}$ which is equivalent to a significant difference between such totals of

$\sqrt{4.3 \times 4 \times 2 \times 2.262}$* = 13.4 units.

The yearly Variety Totals are :—

	A	B	
Year I	24	32	half pound units.
II	20	20	
III	32	64	

Only in the final year is the difference between varieties greater than 13.4 showing that the response of Variety B to the good season in the third year is much more pronounced than that of A. In fact, it might be said that it is this capacity in Variety B of making full use of favourable conditions that is largely responsible for its superiority over Variety A.

XII. Perennial Crops.

Perennial and semi-perennial plants such as orchard and plantation crops, sugar-cane, bananas, tropical fodder grasses, &c., present, to the field experimentalist, additional problems not encountered in dealing with the ordinary annual arable crops. The extreme type of these perennials is found in the fruit orchard where the yield data come from a limited number of relatively large trees. The trees themselves are generally far from uniform in their genetical composition, and consequently, also in their potential yielding capacity. In any old orchard, there will almost certainly be several age classes. Even where the trees are all of the same age, it will be found that some bear early and reach their maximum quickly while others may be slow in maturing, but continue to yield heavily for a much longer period. The trees are widely spaced and, therefore, only a relatively small number can be included in a single plot as, apart from the question of acreage available, if the plots are made too large, the major soil fertility differences within the blocks will counteract the advantage gained by increasing the number of trees per plot. Even where the number of trees is reduced to a minimum, at an average spacing of 25 feet by 25 feet, the plot size will be in the neighbourhood of $\frac{1}{8}$th to $\frac{1}{4}$th of an acre, and the effects of soil differences within plots will be considerable. The root spread per plant is extensive, and makes the inclusion of non-experimental border trees essential to avoid edge interference. The skill of the field staff as regards pruning, harvesting, spraying, &c., has a decided influence on the total yield given by any one tree. The crop is a perennial and the differential response of the individual plants to the varying weather conditions from year to year introduces a further uncontrollable variation factor. The yield data alone does not necessarily measure the full effect of any particular treatment. The quality of the produce is often quite as important as the quantity. The rate of growth, root spread, susceptibility to disease, &c., may be greatly improved without any immediate effect being reflected in the yield data.

The subject of experimentation with perennial crops is much too large to be discussed at any length in the present article. It is a question that is at last receiving a reasonable measure of attention, and the technique is gradually being improved. This is particularly beneficial to those working with tropical crops as the valuable agricultural produce of the tropics comes largely from orchards or plantations as, for example, cocoa, rubber, tea, citrus fruits, &c. It is intended to complete this section by giving a very brief summary, in the light of existing knowledge, of the main factors that should be considered in designing an experiment with a perennial crop.

(*a*) *The use of uniform planting material.*—Wherever possible, seedling trees should be avoided for experimental purposes. The vegetative method of propagation is much more likely to produce similar types of tree, and the planting material should come from the same parent stock. Where grafting or budding processes are involved, every effort should be made to standardise both the rootstock and the scion. Where the experiment is to be superimposed on established plantations, a locality in which the trees are all of one age class should be selected.

(*b*) *Size of Plot.*—On account of the wide spacing required by most orchard crops, plots of larger size than those recommended for annual crops will usually be necessary. Each plot should contain ten or more trees; with an average orchard spacing, this will give a plot size of approximately $\frac{1}{4}$ acre.

(*c*) *Lay-out.*—Probably the Latin Square is to be preferred, as any one experiment will extend over a considerable area of land and this arrangement most effectively reduces the error due to soil fertility differences.

(*d*) *Cultural Treatment.*—The trees should be given parallel treatment as regards pruning, harvesting, soil cultivation, &c. Even the difference in skill and care between two expert pruners or pickers is sufficiently large to produce a significant effect on the ultimate yields.

(*e*) *Border Rows.*—In most yield trials, non-experimental guard rows between plots will be necessary to obviate edge interference and prevent any one treatment from influencing the trees on adjacent plots. The most efficient system, but one which utilises a large area, is to allow a separate guard row for each plot, so that there will be two guard rows

* Value of t for n=9.

between adjacent plots. Each tree in any one guard row is given the same treatment as the plot to which it belongs, but the yields are not entered in the experimental records.

(*f*) *Individual Tree Records.*—Most authorities recommend the separate recording of the yields of every single tree in the experiment. Many purely commercial growers keep such records in order to allow them to eradicate non-profitable yielders. In experimental work, individual tree records make it possible to ascertain the variation within plots, and may even demonstrate the advisability of eliminating particular blocks showing undesirable heterogeneity. Yield data for each tree often prove invaluable in future experimental work. For example, it has been suggested that, where single tree records are available over a number of years, the trees may be classified into groups in accordance with their known yielding capacity. Thus, each group will be composed of so many similar trees; the group can then be used as the block unit, instead of the same number of trees in juxtaposition. Treatments will be randomised among the trees belonging to any one yield group, the variation due to differences between groups being entered in the analysis of variance by calculating the S.S. due to groups in place of the usual S.S. Blocks.

(*g*) *Combined Yields.*—Most trees have a definite fruiting period during the year, and, in consequence, the yield data can be grouped according to year as well as according to treatment and block. In orchard crops where there is a tendency to yield heavily every second year, statistical analysis applied to the combined yield of plots for two consecutive harvests has obvious advantages.

Furthermore, it is possible and often advantageous to use previous records to work out an analysis of variance based, not on the actual yield data, but on the difference for any plot between current yields and those for the preceding period (8).

(*h*) *Classification of the Produce.*—The bulk yield per plot alone is only of limited utility. The produce after harvest usually has to be classified into 1st, 2nd, 3rd class and scrap: the statistical analysis may be limited to the yield per plot of marketable produce, but an estimate of the percentage of each quality in the saleable fruit is also essential if correct conclusions are to be formed. With many crops, chemical analysis may be deemed necessary in order to assess the relative quality of the produce.

(*i*) *Other Records.* — The yield data alone represent only a small part of the total information that should be collected. In many experiments other factors are equally important in estimating the effects of treatment as, for example, girth increment, spread of the tree, annual wood growth, fruit bud productivity and the percentage of shedding, &c. Observations too regarding the general tone and vigour of the trees and the prevalence of fungal and insect attack and other similar cultural details are also of value. All these points serve to emphasize the fact that experimentation with a perennial crop must be tackled in earnest from the outset. It is a lengthy, expensive, and often disappointing task. Before conclusive results can be expected the experiment must be carefully designed and efficiently supervised from start to finish. Whatever system is followed, the cost of experimentation will be considerable, and it is essential to justify this outlay by that attention to detail which alone will attain the ultimate objective.

Statistical Analysis of the Yield Data from Perennial Crops.

The analysis is not quite the same as that described in Example IX for serial experiments. Perennial plots differ in that the plots and the blocks remain the same for the duration of the experiment. In order to illustrate the method of calculation it is proposed to work out an analysis of variance for the yield data given in Example IX, treating the yields as if they represented the data from a plant, first and second ratoon crop of Cotton carried on for a three year period.

Example X.

Table Xa.—Yield Data in lbs. per plot x 2.

Year.	No. of Block.	Variety. A	Variety. B	Totals Across.
1	1	6	9	15
	2	7	8	15
	3	7	7	14
	4	4	8	12
Totals for 1st Year's Crop		24	32	56
2	1	3	5	8
	2	5	4	9
	3	7	4	11
	4	5	7	12
Totals for 1st Ratoon Crop		20	20	40
3	1	10	16	26
	2	6	20	26
	3	8	15	23
	4	8	13	21
Totals for 2nd Ratoon ..		32	64	96
Totals for 3 Years ..		76	116	192
Block Totals	1	19	30	49
	2	18	32	50
	3	22	26	48
	4	17	28	45

It would be permissible to take the final section of the Table showing the Block totals for each variety and, treating it as a 4×2 Randomised Block lay-out, calculate the variance of error. This method, however, would extract only a portion of the information contained in the data and at the same time would give an estimate of error based on a relatively small

number of variables, and make the measure of significance unnecessarily large. It is much better to treat the experiment as made up of four blocks, two treatments, and three crops, for which a total of 24 plot yields is recorded. The only difference from Table IXA is one of block arrangement, so that the calculation for the following factors is identical to that already given in Example IX.

Correction Factor = 1536

Total S.S. = 400 having 23 degrees of freedom.

S.S. Treatment = 67 having 1 degree of freedom.

S.S. Season = 208 having 2 degrees of freedom.

S.S. Interaction, Season × Treatment = 69 having 2 degrees of freedom.

Working now with the new Blocks totals,

$$\text{S.S. Blocks} = \frac{49^2 + 50^2 + 48^2 + 45^2}{6} - 1536 = 2.$$

There are only four blocks, so that this S.S. has three degrees of freedom.

The next step is to calculate the total S.S. of the plots irrespective of seasonal effect. This is obtained from the variety totals for each block as shown at the bottom of Table Xa.

Combined Treatment × Block S.S. =

$$\frac{19^2+18^2+22^2+17^2+30^2+32^2+26^2+28^2}{3} - 15363 = 78$$

with 7 degrees of freedom.

The Interaction of Blocks and Treatments, *i.e.*, the S.S. for parallel plots irrespective of Season = Total S.S. (excluding Season) – (S.S. Treatments + S.S. Blocks)

= 78 – (67 + 2)

= 9 having 7 – (1 + 3) = 3 degrees of freedom.

This final S.S. provides an Error Variance by means of which Treatment or Block Totals for the whole three-year period can be compared by the *z* test. It can be termed Error (a).

The Seasonal effect must next be computed before the full analysis of variance can be given. The S.S. Season and the Interaction S.S. for Season × Treatment have already been calculated. As the blocks are the same in all three years, there is still the interaction between block and season to estimate. The Block × Season totals are given in the last column of Table IXA.

Combined Block × Season S.S. =

$$\frac{15^2 + 15^2 + 14^2 + 12^2 + 8^2 \ldots\ldots 21^2}{2} - 1536$$

= 225, having 11 degrees of freedom.

Interaction S.S. Block × Season

= 225 – (Season S.S. + Block S.S.)

= 225 – (208 + 2)

= 15, having 11 – (3+2) = 6 degrees of freedom.

Error (*b*) = Total S.S. – the sum of the S.S. for all the other factors, including Error (*a*): it has the residual Degrees of Freedom.

TABLE XB.—COMPLETE ANALYSIS OF VARIANCE.

Due to	Sum of Squares.	Degrees of Freedom.	Variance.
Total	400	23	—
Treatments ..	67	1	67.0
Blocks	2	3	0.7
Error (a)	9	3	3.0
Seasons	208	2	134.0
Interactions :			
Season × Treatment	69	2	34.5
Season × Block ..	15	6	2.5
Error (b)	30	6	5.0

Application of the *z* test demonstrates significance when the variances for treatment and Error (*a*) are compared, and when the variances for season and interaction of season x treatment are compared with error (*b*). The *z* test gives a negative result when applied to the variance for blocks or the interaction of block × season, proving that there is no great fertility differences between blocks and that the blocks have reacted similarly to the varying seasonal conditions.

Using Error (*a*), a difference between variety totals for the three crops greater than $\sqrt{3 \times 12 \times 2} \times 3.182$* or 27.0 is significant, proving that, over the three-year period, variety B is definitely better than A.

Using Error (*b*), a difference between the variety totals for any single year's crop greater than $\sqrt{5 \times 4 \times 2} \times 2.447$* or 15.5 is significant.

The yearly variety totals are :—

1st Year	..	A 24	B 32
2nd do.	..	A 20	B 20
3rd do.	..	A 32	B 64

Once again, it is only in the 3rd year's crop that variety B has shown itself to be significantly better than A. Hence, unless observational data provide a different explanation, one could conclude that Variety B was a more successful ratooner than Variety A.

It is also possible to use the same standard error to compare the difference in yield between plant, 1st and 2nd ratoons of any variety. In Variety A, as far as statistics can show, the ratoons have yielded neither better nor worse than the plant crop. In Variety B the second ratoon has shown itself to be significantly better than either of the preceding two crops. It should be clearly understood that in an experiment of this nature the effect of season as calculated, represents the combined influence of two factors, namely, the climatic conditions and the age of the plant. It is not possible from the yield data to separate these two items in the analysis of variance. In consequence one cannot state with any certainty whether the high yield of variety B in the 3rd year is due to a favourable season or to the fact that it tends to give its best yields in the older ratoon crops. The latter explanation is somewhat improbable, however, as with most average crops the plant and earlier ratoons are the most productive.—(*To be concluded.*)

* Value of t.

PLANT BREEDING IN SOUTHERN NIGERIA.

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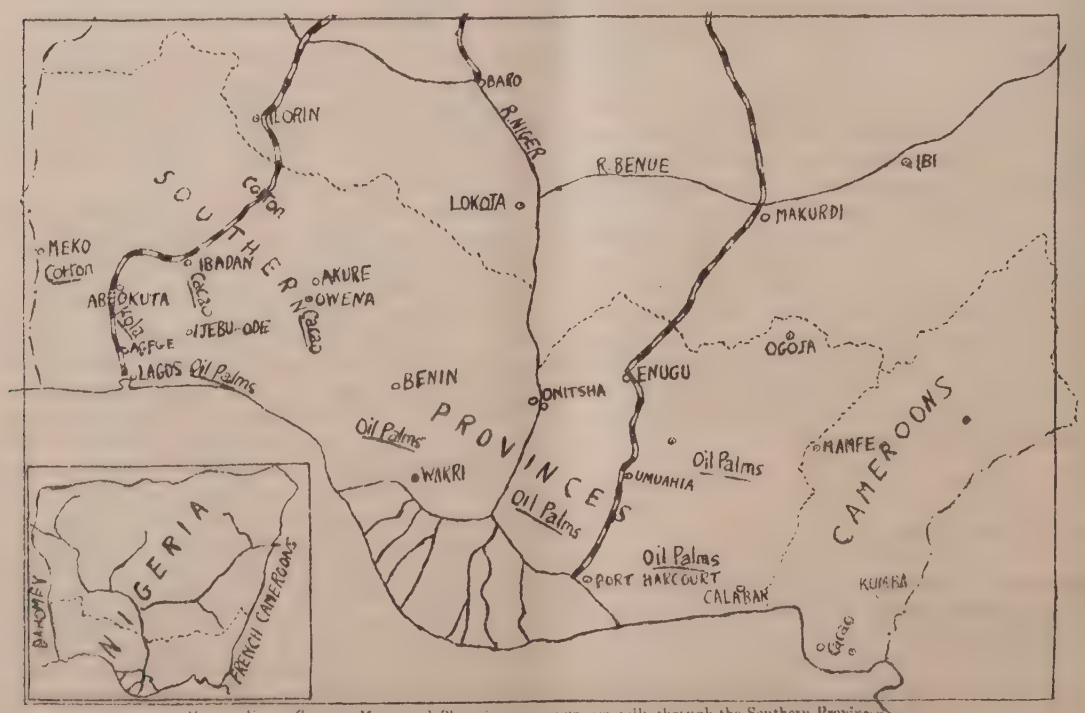
While a number of technical papers has been published from time to time, no general review has as yet been given of the methods and progress of plant breeding in Southern Nigeria. Both plant breeding and plant pathology are undertaken by the botanical section of the Agricultural Department, following the recent amalgamation of the botanical and mycological sections.

Plant breeding is at present organised on an extensive basis, particular attention being paid to the agricultural aspects of the problems. Preliminary work is undertaken with a maximum number of crops and of varieties or strains of each crop. When such material has been worked over, an attempt is made to produce homozygous strains which will prove suitable to the conditions as they exist. The ultimate object with all selection is yield, which generally includes considerations of disease resistance. Once the selections have passed the preliminary stage, when pure lines have been obtained, a definite breeding programme can be initiated. At the present time this stage has been reached only with cotton and edible beans.

In the Southern Provinces permanent crops are of supreme importance, but the progress of initial selection with these will of necessity be slow. Consequently the planting up of test plots at all experiment stations, appropriate to the particular crop, is proceeding apace on the general lines later described for the oil palm yield test blocks. Side by side with plant selection, it has been found necessary to carry out much work of an investigational nature, involving a study of the general behaviour of the crops to be selected. With some crops it has been found advantageous to make a collection of planting material from native farms through the Superintendents of Agriculture at the out-stations, to form the basis of the preliminary selection. This procedure was adopted with edible beans, cassava and chillies, and is now being followed with yams.

The Southern Province laboratories are situated at *Moor Plantation, Ibadan,* the departmental headquarters and principal experimental station in the South. Most of the investigations are centred there, and are supplemented at the out-stations by experiments which are in the charge of African assistants trained by the botanical section. Distance proves a serious handicap in that periodic visits only can be made from headquarters. This is overcome, however, by maintaining very close co-operation with the respective Superintendents of Agriculture who keep a general supervision over all such botanical work.



Note.—Yams, Cassava, Maize and Plantains are grown generally through the Southern Provinces.

A brief resumé of botanical investigations at the out-stations follows. *Agege*, in the Colony close to Lagos, is a small station at which attention is paid chiefly to fruit, although small plots of other permanent crops are being established with selected seed. *Owenna*, a small sub-station to *Ibadan*, has been opened this year, and will be used to test the progenies of the Ibadan cacao selections. *Benin*, is noteworthy on account of an extremely humid climate and very acid soil. This station is the probable future centre for oil palm investigations, though kola and coffee have also been planted there. The station at *Onitsha* was only recently opened, and is the proposed centre for testing the progeny of kola selections. At *Umu-ahia*, oil palm selections have been established with selected seed from the mature plots at *Calabar*.

Oil Palm.

The oil palm (*Elaeis guineensis*, Jacq.) is the most important crop of Nigeria and grows wild throughout the South. Its importance may be gauged by the fact that palm oil is an essential item of the dietary of eight and a half million inhabitants, and that no less than 116,060 tons of oil and 309,061 tons of kernels were exported during 1932 (7), a year of exceptionally low prices.

Although the oil palm grows wild, the right of exploitation is individually or communally owned and is the subject of many laws and customs among tribes inhabiting the palm belt. The recent policy of the Department has been to encourage small native owned plantations, either by thinning the present groves, planting seedlings and eventually cutting out the old trees, or by planting in cleared land *de novo*. Thus a demand for seed from high yielding trees has arisen. Secondary problems include testing the merits of the different varieties, the elucidation of the inheritance of fruit form, and a general developmental study. The oil palm is at present free from serious insect pests or diseases, and the need of selection for any form of resistance has therefore not yet arisen.

Plantation palms established at Calabar include the recognised six Nigerian fruit forms; the ordinary thick and thin-shell, the green-fruited thick and thin-shell, and the mantled thick and thin-shell forms; but unfortunately, with the exception of the first two, the number of mature palms of each form is small. These palm plots were planted from 17 to 20 years ago and individual yield records have been kept for the past eleven years. At no other experimental station are mature recorded palms available.

Selections (2) were made during 1928 from among the highest yielding palms of all the six forms, and the self fertilization of the inflorescences was commenced. Hill and Mason's method (1) of controlled pollination has been used throughout. The progenies of these oil palm selections have been, or will be, planted at the experimental stations in what are termed "yield test blocks", which are designed to test, simultaneously, the kernel and oil yields of both the selections and also the different fruit forms. Fisher's system of randomised blocks has been adopted with the single tree as the experimental unit. Each yield test block contains one main test, in which is included the most promising selection of each form, together with progeny of unselected trees growing wild in the "bush". In addition, subsidiary plots have been planted to test the progeny of the various selections of each fruit form *inter se*. Two complications have arisen in that most of the Calabar selections are certain to be heterozygous for fruit form characters, an unavoidable contingency in such preliminary work, and that the method of controlled pollination has not proved entirely satisfactory. Nevertheless, Calabar material has been distributed to all the experiment stations, and the method of controlled pollination will now be re-explored at Ibadan. To assist in the working out of the inheritance of fruit form a number of crosses has also been made. The present programme involves a total of some 36 acres of yield test blocks divided between the experiment stations. Approximately two-thirds of this area are already established, and the first planted portions are now beginning to fruit. In addition, observations are being carried out regarding leaf production, flowering and fruiting on a limited number of palms at Ibadan, Benin and Umu-ahia. In this way it is hoped that knowledge will be gained about the behaviour of oil palms under varying climatic conditions. Certain yield data for the Calabar palms have already been published (2 and 3).

Cacao.

Cacao (*Theobroma cacao*, Linn.) is mainly confined to the South-western Provinces, where it is a crop of major importance. The predominant variety is yellow Forastero, chiefly of the amelonado type. Selection with cacao was begun in 1930. From the material available, a small field on Moor Plantation in which individual tree records had been kept for the past 12 years, it has been found possible to select several trees which are considered to be genetically superior for yield. Incidentally, the average annual yield of the plot in question is equivalent to 900 lb. of dry cacao per acre. On account of the failure to establish cacao at Benin and Umu-ahia and the lack of suitable land at Moor Plantation, the sub-station at Owenna was opened. A further area for testing selections, and for disease control trials, is now being sought in the neighbourhood of Ibadan.

As a result of the experiments on the controlled pollination of cacao (4 and 6), little difficulty was encountered in obtaining an adequate supply of self fertilized seed from the selected parents. This seed has been germinated and is to be planted during the coming wet season (1933). On Moor Plantation the selfed progeny of ten superior trees has been planted out in a latin square over an area of two acres, with each unit consisting of four trees. Temporary and permanent shades of

banana (*Musa* sp. Linn.) and Immortelle (*Erythrina umbrosa* Linn.) respectively were established the previous year, together with *Calopogonium mucunoides* Desv. as a ground cover. At Owenna, a block of eight and a quarter acres has been laid out to test the relative merits of planting cacao at eight, ten, and fifteen feet square, thus comparing the prevalent close planting methods of the Nigerian peasant farmer with trees at wider spacings. The block is divided into nine plots, each 0.687 of an acre, and in order to reduce border effect, each plot is of square formation, surrounded by a non-experimental row of trees at the same spacing. The three plots wherein the spacing is at fifteen feet are further used to reduplicate the Ibadan progeny trials. The Owenna site is surrounded by heavy forest, and a temporary shade of *Crotalaria* sp. Linn. only is to be used. Small plots are also to be established this year at Agege and at Onitsha, the latter station being outside the limits of the present cacao country.

The relative merits of cross pollination and self pollination will receive attention this year, a problem which was considered of importance by Professor Cheesman of the Imperial College of Tropical Agriculture, Trinidad. At Ibadan, self fertilized seed has been used to supply stocks on which scions from the selected parent trees will be budded. This will thus contain clones of the selected trees, and will consequently afford greater opportunity for providing appreciable quantities of seed, should any of the selections be proved to transmit desirable characteristics to their seminal offspring. It will be noted that this selection programme is based on the eventual production and distribution of seed from proved parent clones. No distribution of budded progenies can be contemplated under the existing conditions. Moreover, recent work in the Dutch East Indies (8) seems to suggest that, where yield is the criterion, seminal offspring are preferable to vegetative. Minor studies in cacao, in the main supplementary to selection, and covering a wide field have been undertaken. The introduction of varieties from abroad is to be limited to the progeny of two Trinidad trees, which have been proved to transmit high yielding capabilities (9), and which should serve as an interesting comparison with Nigerian strains.

Kola.

The planting of kola (*Cola acuminata* Schott et Endl.) has increased considerably during recent years. The nuts are chewed as a stimulant, more especially in the Northern Provinces, and form an important article of local commerce. Formerly large quantities were imported from the Gold Coast and Sierra Leone, but there is evidence that the local supply will soon make Nigeria self supporting. Selection in kola has been handicapped by the absence of individual records, either of yield or of type. Observations were therefore commenced in 1930 with the mature trees on Moor Plantation, and the younger trees at Benin and Umu-ahia are included as they come into bearing. Systematic work with the technique of controlled pollination is now to follow on lines similar to those employed with success in cacao.

There are two factors to be considered in the preliminary selection with kola :—yield, for which the results of several more harvests must be awaited; and colour of the cotyledons, with which a start can be made this year. The price of kola is governed largely by the percentage of white or lightly coloured nuts produced. Colour in the cotyledons varies from white through shades of pink to full red. An experiment in pruning and other cultural treatments for yield improvement has given statistically significant results in favour of partial ring barking, but because great irregularity has occurred from tree to tree, confirmation of these results will be sought.

Citrus.

The cultivation of citrus fruits (*Citrus* spp. Linn.) seems likely to extend in the future, and may become an important minor industry. There is a good local demand for sweet oranges, and, to a lesser extent, for grapefruit and other citrus fruits. At present the demand exceeds the supply. There is also a possibility of a future export, provided the production of improved fruit types becomes consolidated. The present citrus varieties, while esteemed in Nigeria, are of very doubtful value for export. During the past year the first steps were taken to initiate systematic citrus selection. As yet this work is confined to Ibadan and Agege, but the planting up of small test plots will be extended to all experiment stations in the course of the next few years. Material prepared by Mr. J. R. V. Smyth, Superintendent of Agriculture, has been used to establish at Ibadan and Agege tests of grapefruit and sweet orange scions on seven stocks :—*C. aurantium*, *C. limonia*, *C. sinensis*, *C. paradisi*, *C. maxima*, *C. aurantifolia* and *C. nobilis* var. *deliciosa*. The successful introduction of new scions by means of budwood was made last year from Sierra Leone, through the courtesy of the Director of Agriculture of that Colony, and this year further introductions are to be attempted from America and the West Indies. At the same time the best local types have not been neglected. In this way it is hoped to produce high yielding strains which will prove not only acceptable to the local demand but also of sufficient quality to meet the requirements of foreign markets. The incidence of pests and diseases will undoubtedly provide a major consideration in the solution of this problem.

Coffee.

No breeding in coffee (*Coffea* spp. Linn.) can be contemplated for several years. Liberian types (*C. liberica* Hiern.) are grown with success in this country, and the main problem is to obtain a coffee which will thrive under the climatic conditions of Southern Nigeria and which will have a flavour, and consequently a market price, superior to these. In the present state of the world production of this commodity, a profitable

export cannot be anticipated, but the local consumption tends to increase among the indigenous population, and coffee may well become a valuable minor crop for some Nigerian farmers. The initial collecting and planting of different varieties has been undertaken among which are Robusta types (*C. robusta* Linden) recently obtained from Java and the Gold Coast, through the courtesy of the respective Departments of Agriculture. Fortunately coffee comes into bearing at an early age, and as the planting of introduced varieties has already taken place at several out-stations, data on yield and suitability to different localities will soon accumulate. It is possible that the desired type may be obtained from one of the countries where considerable work has already been carried out with this crop.

Cotton.

Cotton (*Gossypium* spp. Linn.) selection was commenced in 1923, and is confined to Ibadan. The areas served are the cotton growing districts of the South-western Provinces, the only part of the South where this crop is extensively grown. The indigenous cotton of these districts, a variety of *G. peruvianum* Cav., was found to be incapable of improvement, and Allen cotton (*G. hirsutum* Linn.), which had been distributed over a few years to native farmers, proved unsuitable. An improved selection from the indigenous cotton of the Ishan division of Benin Province, a variety of *G. Vitifolium* Lamk., was bred up (10), and, after successful trials, was first distributed to the farmers as Improved Ishan Strain A in 1927. This variety has now replaced Allen cotton entirely, and has almost completely superseded the local indigenous cotton. It is still considered desirable to continue an annual single plant re-selection at Ibadan for the maintenance of the many valuable characters of this strain. A routine of seed multiplication has been evolved (11), in which the new seed, after preliminary multiplication by the department on Moor Plantation, is grown under supervision in one selected district at Meko by native farmers, whence in turn the general Ishan cotton growing area receives an annual supply of pure seed.

Ishan A has suffered from the general fall in cotton prices and, at the moment, the area under cotton in Southern Nigeria is much reduced. Cotton is, however, always grown in these areas to supply the considerable demand of the local weaving industry; but production for export, governed as it is by current prices, fluctuates widely. In general, Ishan Strain A is entirely suitable, but the least desirable feature is the somewhat coarse or rough character of the lint; and with the present reduced demand for premium cottons, this defect is probably more serious than it would be in more normal times. Mr. C. J. Lewin commenced a crossing programme several years ago between Ishan A and a sister strain Ishan E, in an attempt to produce a similar strain having a more acceptable lint. As a result of this cross several promising strains have been fixed by continual re-selection and have now reached the stage of preliminary field trial on Moor Plantation. Recently, acting upon the advice of Dr. S. C. Harland, the Empire Cotton Growing Corporation's geneticist, Ishan A has been crossed with Sea Island cotton (*G. barbadense*, Linn.), and it is proposed to back-cross with Ishan A for several generations with the hope of grafting a superior lint on to Ishan cotton.

Edible Beans.

Over a number of years it has been shown that the fertility of the soil on Moor Plantation can be maintained by the use of green manures in the standard rotations (12). In 1927 selection work with edible beans was commenced by Mr. C. J. Lewin with the object of finding a legume which would both yield an edible crop and also prove adequate as a green manure. At first attention was confined to Lima types of *Phaseolus lunatus*, Linn., and several strains underwent extensive trials. In 1930 a large collection of local edible beans was obtained through the Superintendents of Agriculture, and all the types were tested out and classified at Ibadan. Many exotic varieties were also tried, and an account of these bean investigations will appear shortly (5). As a result of preliminary trials, the most promising type was found to be a selection of the indigenous Popondo (*P. lunatus* forma *macrocarpus* Van Es.). This selection has already been incorporated in the standard rotations on Moor Plantation, where it appears to be a successful late green manure, and a few initial trials on Native farms are in progress this year. At Ibadan, Popondo sown in June through a crop of early maize gives an average yield of 400 lb. of dry shelled beans per acre. Should Popondo be a success, which now seems most probable, the prospects of green manuring extension work will be very greatly enhanced.

The present white beans of Popondo, while suitable for local markets, must be improved, if the possibility of a future export, which has been kept in view throughout this work, is ever to be realized. In this direction, progress is being sought through hybrids between the local selection and various introduced types. Artificial crosses have been found to be both tedious and uncertain, and crossing by natural means is now attempted. By sowing two types in the same stands, and by adjusting the sowing dates so that the parents flower at the same time, a satisfactory percentage of natural crosses is generally obtained. All the seed harvested is sown at a close spacing, when the few crossed seedlings produced can be determined at an early age by their vegetative characters; all other plants are then rogued out.

Cassava and Yams.

The progress attained with the preliminary selection of other crops has enabled attention to be devoted recently to cassava (*Manihot* spp. Tourn.) and to yams (*Dioscorea* spp. Plum.), two basic food crops. Work with cassava was begun first, and was initiated by a collection of material

on the lines described for beans. After the preliminary trial in observation plots, carried out last year, the varieties are now grouped for testing out *inter se*. In addition to taxonomic observations, attention is being paid to yield, quality, time to maturity and especially resistance to the mosaic disease. A similar collection of Nigerian yams was begun towards the end of last year, and at the time of writing 157 separate samples have been planted on Moor Plantation. Taxonomy, agricultural value and disease resistance will be the characters mainly studied.

Maize.

Maize (*Zea Mays*, Linn.) is grown extensively in the South as the local cereal crop, but there is at present no appreciable export. Two crops are obtained a year in the Western Provinces, and one in the Eastern Provinces. No special problems have arisen so far with maize, and no work has, as yet, been attempted on this crop by the botanical section, though ear to row selection is practised at Ibadan by the Agriculturists.

Spices.

A representative collection of chillies (*Capsicum* spp., Linn.) has been grown at Ibadan for one year, and has been found to consist of about equal proportions of *C. annuum*, Linn. and *C. frutescens*, Linn. A very great diversity of fruit form has been noticed, and it is probable that this variation is due to two causes: firstly, the almost certain admixture of types in the original samples which were bought in local markets, and secondly, the heterozygous nature of the varieties themselves. It is proposed to multiply up the main types this year sufficiently to obtain commercial reports. Chillies, grown on a small scale, might provide a useful export. Similar work has been commenced with peppers (*Piper* spp. Linn.), but these are perennial vines, and do not flower till several years after planting, so results cannot be expected for some time.

Minor Crops.

Collections of pineapples (*Ananas sativus*, Schult.) and bananas (*Musa* spp. Linn.) are in progress this year, and work will follow upon the usual lines. An area on Moor Plantation has been allocated to the growing of a few plants of each of the miscellaneous perennial economic crops. Planting will commence shortly, and material will thereafter be established as it is obtained. A preliminary study of native vegetables and other indigenous annual crops of economic value is also to be undertaken.

Plant Pathology.

Work on plant disease is co-ordinated with the general plant breeding programme. While particular attention is naturally paid to the pathology of economic crops, a general survey of plant diseases is gradually being made to augment the somewhat scanty data at present available.

An experiment concerning the control of Black Pod (*Phytophthora palmivora*, Butl.) of cacao was commenced by Mr. T. Laycock in 1931. Four native cacao farms in the Ibadan area, comprising some three and a half acres in all, are treated respectively with Bordeaux Mixture spray, a Copper dust, a Sulphur dust and a treatment consisting of clean sanitation only. Each of these peasant farms was divided into two plots when the experiment started, one plot is entirely untreated, and the other receives one of the above treatments. The treated portion of each farm was originally heavily pruned and thinned. Spraying and dusting are carried out three times a year; in March at the beginning of the rains, in June during one of the heaviest periods of rainfall, and in August during the short dry season when there is normally a break in the rains of three or more weeks. Labour costs are kept to show the number of man-days each operation entails. Although the experiment has only run for a relatively short time, the crop yields so far recorded afford certain tentative conclusions, and are of interest in that these small peasant holdings show yields varying from seven to 16 cwt. of dry cacao per acre during the season 1931-32 (calculated at 43 *per cent.* of the weight of wet beans harvested). The initial heavy pruning tended to lower the yield of the following crop on all treated plots, as compared with the controls, but with the completion of the first full year after treatment the yields of both halves of each farm became approximately equal. In the second year, with one exception, the treated plots have taken a lead over the controls. This lead is by no means large, and it is doubtful whether it will be maintained, let alone increased, as the trees have probably grown too long under the close planting conditions of native farming to possess at this stage sufficient rejuvenative capabilities. In the second year, spraying and dusting have reduced the percentage of diseased cacao to two or three *per cent.* of the total crop, as compared with five and a half to eleven *per cent.* for the controls. Spraying, generally believed to be more efficient than dusting, has cost seven man-days per acre per application, and at present holds only a small advantage over dusting in the reduction of the percentage of diseased pods. Both the dusts that are used have proved easier to apply than the spray, and have cost five man-days per acre per application. A knapsack bellows type of apparatus has been employed for the dusting, but this year a rotary type of blower is to be tried, which it is hoped will prove more efficient. In the plot where an attempt is made to control disease by clean sanitation, husks are buried after breaking, and diseased pods and branches are cut off and removed. This treatment does not yet appear to cause any reduction in disease compared with the incidence upon its control, which has happened to be the lowest among all the control plots in both years. It would appear doubtful whether clean sanitation could cause an appreciable reduction of the percentage of disease after only two years, in a farm which has been practically uncared for during the previous ten, since by sanitation the sources of infection are not killed directly as on the sprayed or dusted plots, but

can at most only be obliterated gradually. As has already been mentioned when dealing with cacao, it is hoped shortly to establish an area under this crop in the neighbourhood of Ibadan, which will provide facilities for further experiments in disease control.

A disease which produces a tuber rot of yams was first noted on Moor Plantation about five years ago, and the incidence has steadily increased in the rotations which are practised on the plantation. The disease causes the formation of a dry spongy layer which eventually envelopes the entire tuber; such tubers are almost useless as planting material and when stored soon become wholly decayed. Two approaches towards the solution of this problem are being explored. Selection for resistant types among the yam varieties recently collected will be attempted, and the organisms which are associated with the disease have been cultured, and inoculation experiments have been set up under controlled conditions in the laboratory. Similarly, with cassava, selection for resistance to mosaic is being carried out among the various types that have been obtained.

In conclusion, the writers wish to acknowledge their indebtedness to all present and former members of the staff of the Nigerian Agricultural Department who have assisted so generously at one time or another, and without whose assistance the programme of work could not have proceeded; and especially to past members of the staff of this section. It is unfortunately impossible to mention all individual names, but the help received has been greatly appreciated, and it is hoped that this general acknowledgment will be accepted.

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PAPAW SELECTION.

According to J. D. J. Hofmey (*Farming in South Africa*, VIII, 1933) selection of papaws (*Carica papaya* L.) was started at Nelspruit Subtropical Horticultural Research Station, South Africa, in 1931. The chief points in the selection programme are (*a*) keeping and shipping quality; (*b*) suitable shape and size for packing; (*c*) colour; (*d*) eating quality; (*e*) thickness of flesh; (*f*) length of fruit stalk, a long stalk being useful to prevent damage from overcrowding; (*g*) disease resistance; (*h*) yield and vigour. In the course of the investigations several beliefs commonly held by growers have been disproved. It has been found, for instance, that the strain can definitely be improved by selection in spite of the plant being dioecious, particularly if selections are made from the centre of the plantation, when there are neighbouring groves. Again, it was found that no ground exists for the assumption that the male trees are the more vigorous; hence the elimination of the more vigorous seedlings when transplanting in the hope of destroying the males is merely a destruction of the best plants; vigorous trees produce fruit early, for a longer period and lower on the stem, all of which are desirable characteristics. The belief that the males comprise at least 70 per cent. of the population was also proved incorrect, investigations showing that distribution was about equal. Pollination experiments showed the necessity, moreover, for the presence of male trees, contrary to popular opinion. Arising from the percentage distribution of the sexes farmers are advised to plant four seedlings in a planting hole instead of the usual two. If this is done, the chances that one at least will be a female when the sexes are determined and the plants thinned to one per hole are then 93¾ per cent. and the chances that two will be females, thus allowing the strongest to be retained and greater uniformity obtained, are 68¾ per cent. By this method, too, since mortality among transplanted seedlings is high, the cost of replacement is also reduced, the number needed being reduced to a minimum. In a perfect stand, by thinning to one per hole and leaving a female wherever possible, sufficient males will be left for effective pollination. The theoretical expectancy has been verified in the field. Before storing, the seed should be washed in several changes of water and spread thinly to dry. It will then retain its germinating power for a year. Fermentation of the seed as advised by some growers was found definitely to reduce the germinating power.—(*Horticultural Abstracts*, Vol. III, No. 2, Ab. 253.)

THE CLASSIFICATION OF GROUNDNUT VARIETIES.

With a Preliminary Note on the Inheritance of some Characters.

By T. R. Hayes, M.Sc. (Tech.), A.I.C.T.A.

I. Introduction.

Van der Stok in 1910 was the first to effect an artificial cross of Groundnuts (5), and he found that red colour of testa was dominant over pink colour, a single factor difference being responsible for the character. Badamy (1) showed that Runner was dominant over Bunch, and recently Stokes and Hull (2) confirmed Van der Stok's observation on testa colour. Stokes and Hull found that Runner seeds require a long period of dormancy after reaping before they will germinate, whereas seeds of Bunch varieties will germinate almost at once; they found that this dormancy requirement was incompletely dominant, and pointed out that this character is a distinct advantage when the crop is left in the ground for "hogging off," there being little fear of the groundnuts germinating before the pigs can eat them. The last named authors give a detailed account of their technique of crossing, and some of this information was made available to the writer previous to its publication through the courtesy of the United States Bureau of Plant Industries.

A number of crosses have been made in the Department of Agriculture, the Gambia, with a view to increasing yield. As so little is known of the genetics of the Groundnut, this was made a primary study, but the difficulty is that there are few definite characters, such as presence and absence of colour of testa, which can be used in the study of the inheritance of the plant.

A necessary preliminary, therefore, to the study of characters other than those mentioned above is a detailed study of the botany of the Groundnut, with its numerous varieties, and on intensive examination it was found that many characters could be classified by a system of grading.

A preliminary note on this phase of the work has been already published (3), and it is now possible to give in detail the grades or measurements of each of the 15 characters for all the varieties under observation. With the aid of these, the 40 odd varieties have been classified in a fairly orderly manner.

II. Classification of Characters.

The following notes explain the details of classification for each character.

Corolla Colour.—The number of grades were reduced from six to five to render classification easier. These, like the other grades, are only arbitrary, so that there may be a certain divergence from the particular grade to which the plant belongs, but not enough to enable it to be classified in one of the neighbouring grades. The following varieties, however, may be used as "Standards", *i.e.*, they fit their respective grades so accurately, that the colour scale can be discarded and flowers from the varieties used for reference when examining flowers of other types:—

Grade.	*Variety.*
1	Java White.
2	Small Japanese.
3	Baol.
4	St. Vincent.
5	Falcon.

The colour increases in depth from 1 to 5.

Red Colouring Matter on Standard.—In this case also the number of grades was reduced from six to five. The standards are as follows:—

Grade.	*Variety.*
1	Philippine White.
2	Spanish Bunch.
3	Virginia Bunch.
4	West African (Poona).
5	Zaria.

Colour of Calyx.—As the amount of chlorophyll developed depends to some extent on external conditions, this is not a very dependable character. The difference between pale and dark, however, is usually quite distinct.

Colour.	*Standard.*
Pale	Spanish Bunch.
Intermediate	Spanish No. 8.
Dark	Virginia Runner.

Calyx Teeth.—The Calyx has a serrated edge. The depth of the notches varies from deeply indented to slightly indented. Sometimes the calyx is torn between two teeth and this makes the teeth appear longer than they really are; the calyx should be examined with a hand-lens to get satisfactory results. Fluctuation is considerable, but the difference between short and long is distinct.

Length of Teeth.	*Standard.*
Short	Spanish Bunch.
Intermediate	Virginia Bunch.
Long	Big Japan.

Red Colouration of Stem.—It has previously been noted (3) that this was an unreliable character owing to the variation in shading by the leaves. Consequently the leaves from a lateral of each variety were cut off and the branch pegged down for two weeks prior to examination, to ensure uniformity.

Grade.	*Standard.*
Very Slight	Gudiattam Bunch.
Slight	Spanish No. 5.
Intermediate	Small Japan.
Plentiful	Valencia.

The "very slight" class included at times plants with no trace of colouration at all to the naked eye.

LEAF ATTRIBUTES.—Length of sheath, length and breadth of leaflets, length of rachis, length of petiole, hairs on petiole, and red colouration on the base of main leaflet vein. All these characters were recorded on the pair of fully grown leaflets nearest to the top of the primary branch (Upright). Fluctuation between plants of the same variety in the same stage of growth was surprisingly small.

HAIRS ON PETIOLE.—Four grades were made. The amount of hair present varies under different conditions, especially moisture conditions. In dry periods more hairs are developed than in wet weather. Care has also to be taken to examine leaflets of the same age, because on the older leaves the hairs are deciduous.

Grade.	*Standard.*
1. Only few hairs present	.. Sine.
2. Intermediate	.. Barbados.
3. Present to a marked degree	Gudiattam Bunch.
4. Many present	.. Java White.

With the naked eye it appears that most of the Runner varieties have long and short hairs while most of the Bunch have only long hairs. This requires confirmation under the microscope.

CONDITION OF FLOWERS AT 3 P.M.

Grade.	*Standard.*
Quite faded at 3 p.m.	..Sine.
Intermediate	..Improved American.
Comparatively Fresh at 3 p.m.	..Spanish Bunch.

COLOUR OF TESTA.—The descriptions of colour are taken from the Imperial Institute Reports on Groundnut samples from the Gambia.

OTHER CHARACTERS.—The following characters were examined in detail, but were found to be of no value at present for classification: length of seed, angle between rachis and petiole (morning and evening) angle between petiole and stem (morning and evening). The mean oil content of all Bunch varieties was less than that of all Runner varieties, but not significantly so.

III. Classification of Varieties.

Chevalier (6) divides *Arachis hypogea* into two sub-species, *A. africana* (Runner) and *A. asiatica* (Bunch) corresponding to the *A. procumbens* and *A. fastigiata* of Waldron (7). Chevalier subdivides these into several groups according to seed characters, hairiness, vigour, &c. After a study of much material at Kew and the Museum de Paris, he comes to the conclusion that the study of the varieties of the Groundnut cannot reasonably be carried out without the aid of living material. The classification below depends almost entirely on characters which can only be studied in the living plant, and it was found to be the only possible way of differentiating between forms in the majority of cases.

The following table shows the varieties studied; an attempt was made in the case of each variety to trace it back to its country of origin. With the help of the Agricultural Departments concerned, some information was obtained, but in the other cases the varieties have been in the country of their adoption for so long that their origin is lost.

Variety.	*Country of Origin.*	*Notes.*
Baol	....Baol, Senegal	—
Barbados (Ceylon)	Madras	....Grown in Madras for over 27 years.
Basse	....Gambia	—
Big Japanese	....Madras	....Grown in Madras for over 27 years.
Big Japan (Poona)	Poona	.... —
Chinese	....China	....From consignment shipped to London.
Coinaji	....French Guinea	Brought in to the Gambia for sale by the Coinaji tribe.
Falcon	....Venezuela	....Grown by the Arawak Indians in the Falcon district.
Gudiattam Bunch	Madras	—
Improved American	St. Vincent	....Selected in U.S.A.
Improved Spanish	Rhodesia	....Previously from U.S.A.
Java White	....Rhodesia	....Previously from Northern Australia.
Jumbo	....Rhodesia	....Originally from U.S.A.
Local Poona	....Poona	—
Mauritius Local	....Madras	....Introduced into India about 1900. Origin uncertain.
Madagascar	....Madras	....Grown in Madras for over 27 years.
Natal	....Rhodesia	....Previously from Union of South Africa.
Philippine Pink	....Philippines	—
Philippine White	....Philippines	—
Pondicherry	....Madras	—
Poona Local	....Abhair Farm, India	—
Senegal (India)	....Madras	....Grown in Madras for over 27 years.
Sine	....Sine, Senegal	—
Small Japanese	....Madras	....Grown in Madras for over 27 years.
Small Japan (Poona)	Poona	—
Spanish Bunch	....Central Provinces	A selection by Dr. Youngman from small Spanish Bunch.
Spanish Jalquan	Madras	—
Spanish Poona	....Poona	—
Spanish Nos. 5, 8, 9, 10	Poona	....Imported from U.S.A. and isolated by Dr. Mann.
St. Vincent	....St. Vincent	—
Valencia	....Rhodesia	....Previously from U.S.A.
Virginia Bunch	....Rhodesia	....Originally from U.S.A.
Virginia Runner	....Rhodesia	—
West African	....Madras	....Grown in Madras for over 27 years.
Zaria	....Nigeria	—

From the characters above described the varieties can be grouped as follows:—

GROUP A. (BUNCH).

Corolla colour, pale (grade 2).
Spot, pale (grade 2).
Hairs on petiole, intermediate (grades 2 and 3).
Colour of testa, pale pinkish brown.
Flowers fresh for long period.

This group includes Gudiattam Bunch, Spanish Jalquan, Spanish Bunch, Spanish Nos. 5, 8, 9, 10, Spanish Poona, Poona Local and Natal.

Natal conforms to this type in all respects save that the testa is pinkish brown.

In Spanish Poona there is no record of "Hairs on Petiole."

All these varieties have a number of seeds very deeply ndented.

Gudiattam Bunch and Natal have seeds slightly less indented, on the whole, than the usual Spanish type.

GROUP B. (BUNCH).

Corolla colour, pale (grades 1 and 2).
Spot, deep coloured (grades 4 and 5).
Hairs on petiole, many (grade 4).
Colour of testa, deep reddish brown or deep red.
Flowers fresh for a long period.

This group includes Small Japan (Poona), Small Japanese, Valencia and Java White.

Small Japanese differs from type in that the spot is intermediate (grade 3).

Java White differs in the testa colour which is pale brown. The seed shapes of the members of the group are similar. They have slightly indented or "hump-backed" seeds. Occasionally, however, a well indented seed is found in Valencia.

Small Japan has a much smaller seed than the others.

GROUP C. (BUNCH).

Corolla colour, pale (grade 2).
Spot, deeply coloured (grade 4).
Hairs on petiole, many (grade 4).
Testa colour, pale pink.
Flowers fade earlier than in groups A and B.
Seeds slightly indented.
Philippine Pink is the only member of this group.

GROUP D. (BUNCH).

Corolla colour, deep (grade 4).
Spot, deep (grade 3).
Hairs on petiole, few (grade 1).
Testa colour, pinkish brown.
Flowers fade earlier than in groups A and B.
Seeds slightly to moderately indented.

Virginia Bunch is the only variety examined which falls into this group.

NOTES ON BUNCH VARIETIES.

Characters common to most Bunch varieties and not mentioned in the groups are as follows :—

1. All have sheath length of 30 to 35 mm., except in Virginia Bunch, where it is 23 mm.
2. All have leaf length between 50 and 70 mm. except in Virginia Bunch, where it is 48 mm.
3. All have pale or intermediate calyx colour, except in Virginia Bunch, which has a dark calyx.
4. Virginia Bunch differs greatly in its habit from other bunches.

GROUP E. (RUNNER).

Corolla colour, deep (grades 4 and 5).
Spot, deeply coloured (grades 4 and 5).
Hairs on petiole, intermediate (grades 2 and 3).
Flowers fade early.
Testa colour, pinkish brown.

This group includes Barbados, West African (Indian), Virginia Runner, Falcon, Zaria and Chinese.

With Chinese, the hairiness of petiole has not been recorded.

GROUP F. (RUNNER).

The difference between this group and group E is less marked than the difference between other groups generally.

Corolla colour, deep (grade 4).
Spot, intermediate (grade 3).
Hairs on petiole, intermediate (grades 2 and 3).
Flowers fade early.
Testa colour, pinkish brown.

This group includes Pondicherry, Mauritius, Improved American, St. Vincent, Big Japanese, Senegal and Big Japan (Poona).

With Mauritius, the hairs on petiole were not checked at the same time as the others.

GROUP G. (RUNNER).

Corolla colour, intermediate (grades 3 and 4).
Spot, light coloured (grades 2 and 3).
Hairs on petiole, few (grade 1).
Flowers fade early.
Testa colour, pinkish brown.

The following belong to this group :—Madagascar, Baol, Sine.

GROUP H. (RUNNER).

Corolla colour, deep (grade 4).
Spot, light (grade 2).
Hairs on petiole, intermediate (grade 2).
Flowers fade early.
Testa, pale pink.

Jumbo is the only member of this group.

GROUP I. (RUNNER).

Corolla colour, deep (grade 4).
Spot, very light (grade 1).
Hairs on petiole, few (grade 1).
Testa, greyish white.
Flowers fade early.
Habit not so prostrate as for other Runners.

Philippine White is the only member of this group. It is remarkable in having no red colouration in any part of the plant except on the standard, and this is of a very low grade.

GROUP J. (RUNNER).

Corolla colour, low (grade 3).
Spot, light (grade 2).
Hairs on petiole, many (grade 4).
Flowers retain freshness as long as Bunch varieties.

Local Poona is the only member of this group.

NOTES ON RUNNER VARIETIES.

Varieties Basse, Coinage Pink and Gambia were very mixed. The different types of each have been separated for determining, next year, whether the varieties are a mixture of pure lines or whether we are dealing with heterozygous communities. All types of these varieties, however, seem to conform generally to group G.

Characters common to the majority of Runner, and not mentioned in the groups are as follows :—

1. All have either dark or intermediate coloured calyx except Local Poona.
2. All have leaf sheaths of between 20 and 25 mm. in length except Jumbo, where the length is 32 mm. No record for Chinese and Local Poona.
3. All have leaf length of 40 to 45 mm., with the exception of Jumbo, where it is 60 mm. No record for Chinese and Local Poona.
4. All have non-indented or slightly indented seeds, except Local Poona, whose seeds are moderately indented.

IV. Analysis of F_2 Generation of Valencia (♀) × Sine (♂).

A stand of 159 plants was obtained, but one plant, owing to abnormal environment, failed to come to maturity, and it could only be used in the classification of length of rachis, which was entirely absent in this case. 158 plants were therefore used in the study of vegetative characters; of these, 12 were sterile, and 146 plants remained for the classification of seed characters. Two plants failed to flower at all, and for various reasons one or two further plants could not be used in the study of flower characters.

Number of Seeds.—There is no record of the average number of seeds borne by the two parents, and further, this character is subject to wide fluctuation on account of environment and disease. Badamy (4) puts the seasonal fluctuation in Mysore at ±15 per cent. The yields of the F_2 generation therefore have not been examined for segregation.

The fact that 12 plants out of 158 were sterile indicates that Valencia and Sine have complementary genes for sterility. There appears to be a two factor difference between Sterile and Fertile.

	Sterile.	*Fertile.*
Obtained ..	12	146
Expected ..	9.88	148.12

The table below shows the analysis of the sterile plants with regard to other abnormalities.

Serial number of sterile plant.	Small vegetative parts.	Absence of rachis.	Absence of hairs on petiole.	Five leaflets.	Abnormal habit.	Absence of flowers.
4	—	X	X	X	—	—
12	X	—	—	—	X	—
33	—	X	—	X	X	—
54	X	X	X	X	X	—
56	—	X	—	—	—	X
61	—	—	—	—	—	—
111	X	—	—	—	X	—
125	X	X	X	—	X	X
130	—	—	—	—	—	—
136	—	—	—	X	—	—
137	—	—	—	—	—	—
141	—	—	—	—	—	—
No. of abnormalities in sterile class	4	5	3	4	5	2
No. in total population	11	7	3	20	17	2
Per cent. in sterile class	36.4%	71.4%	100%	20%	29.4%	100%

As the proportion of sterile plants to the total population is only 7.6 per cent., it is apparent that a very high proportion of abnormal characters occurs in the sterile class. It is of interest that the only three plants completely devoid of hairs on the petiole were all sterile. While only two plants entirely failed to flower, three others produced only a very few flowers; two plants, on the other hand, flowered profusely, much more than normally, but the flowers were of about half the normal size. Four plants were quite normal in appearance, and plants similar to these have been noticed occasionally in the field.

Habit.—Valencia, Bunch.
Sine, Runner. F_1, × Runner.

The F_2 generation consisted of Runners and Bunches, and a series of intermediate grades; in addition, there were 17 plants which were so abnormal in habit that they could not be placed in any class. As some difficulty was experienced in deciding whether certain plants belonged to the Runner or Intermediate class, these two classes were grouped together and compared with the number of Bunches. The following figures were obtained:—

	Bunch.	*Runner.*
Obtained	7	134
Expected on 15 : 1 basis	8.8	132.19

There is thus a two factor difference between Runner and Bunch, with Runner dominant.

Colour of Testa.
Valencia, dark red.
Sine, pale brown. F_1, dark red.

In the F_2 generation, segregation was very distinct; in one case only there was a pale brown seed which was slightly darker than those of Sine, and it was quite distinct from the dark red. One plant was also obtained with seeds of a slightly darker shade than those of Valencia.

	Pale brown.	*Dark red.*
Obtained	32	114
Expected on 3 : 1 basis	36.50	109.50

There is a one factor difference between dark red and pale brown, with dark red dominant. There may possibly be one or more modifying factors.

Length of Seed.
Valencia, Long.
Sine, Short.

The figures obtained were:

Short.	*Intermediate.*	*Long.*
13	44	89

Among the Intermediate, and even the Long class, an occasional short seed was found. Long is clearly dominant over short, and as the segregation between Short and Intermediate was fairly distinct, it seems justifiable to group the Intermediate and Long together. Doing so, we get:—

	Long.	*Short.*
Obtained	133	13
Expected (15 : 1) ..	136.87	9.13

There appears to be a two factor difference between Long and Short, with Long dominant.

Length of Rachis.

Valencia ..	13 mm.
Sine ...	13 mm.

The segregation is shown in Table 4 of the Appendix. It appears from these figures that with regard to this character the two parents are the same phenotypically, but not genotypically. There is a clean-cut segregation between plants with very low or no value for length of rachis and those with a low value; there are also indications of several other groups, including two above 13. The appearance of leaves with no rachis is shown in the illustration.

The following hypothesis appears to fit the facts:—Valencia and Sine each have two factors for the expression of rachis length=13. One factor is common to both, and the second factors are different in the two cases and complementary to each other. Calling the common factor A and the differing factors X and Y, we have AAXXyy for the genotype of Valencia and AAxxYY for that of Sine. On this assumption one would expect in F_2 eight different genotypes, of which those giving very high and very low values (AAXXYY and AAxxyy respectively) should each occur once in every 16 plants, whilst the rest would be likely to give intermediate groups, more or less overlapping in their range of values.

The very low group (absent and 2 mm.) gives a ratio of .. .. .. 7 : 152
Expected on above assumption 9.94 : 149.06
The high group (17-19) gives a ratio of .. .. .. 8 : 151
Expected .. .. .. 9.94 : 149.06

Red colouration of stem.
Valencia, Present (P.)
Sine, Very Slight (V.S.)

The results were:—

Very Slight.	*Slight.*	*Present.*	*P.P.*
26	17	86	29

P.P. indicates more colouration than on Valencia.

There was a natural gap between Slight and Present, so the Very Slight and Slight can be classed together, and we obtain:—

	V.S. and S.	*P. and P.P.*
Obtained ..	43	115
Expected (3 : 1)	39.5	118.5

Undoubtedly some lower grades than Sine were present, but fluctuation was so great that further divisions could not be made.

Crinkled Leaf.
Valencia, not crinkled.
Sine, not crinkled. F_1, × not crinkled.

In the F_2 eight plants were crinkled and 150 not crinkled. This factor appears to be due to the meeting of complementary genes. The ratio obtained suggests a two factor difference between crinkled and normal, but more data is required.

	Crinkled.	*Normal.*
Obtained ..	8	150
Expected (15 : 1)	9.88	148.20

Crinkled leaf did not affect the productiveness of the plant, and none of this class was sterile.

With regard to the remaining characters studied, until more data is obtained it would be unwise to define them in terms of factors. No natural gaps were found and arbitrary grades were made. It is evident, however, from the results that, besides main genes, there are present either modifying factors, complementary or supplementary genes, or combinations of these.

Condition of Flowers at 11 a.m.—The flowers were picked early in the morning and left in an open box, indoors. In the preliminary work on varieties, this character was noted at 3 p.m., but it was found in the present case that greater differentiation could be obtained by noting the condition of the flowers earlier in the day.

Valencia .. .. Fresh.
Sine .. .. Faded.

The F_2 segregated as follows:—

Fresh.	*Intermediate.*	*Faded.*
10	88	56

Faded is clearly dominant over fresh, but no natural gap occurred between Intermediate and Fresh; as the Intermediate class included several degrees of freshness, some members might really belong to the fresh class. Modifying factors are apparently at work.

Corolla Colour.
Valencia 2
Sine 4

For frequency array, *see* Table 6. Deep coloured corolla is dominant over pale corolla.

Spot (red colouration on corolla).
Valencia 5
Sine 3

The segregation of this character was as follows:

Grade of Spot ..	2	3	4	5
Number of Plants ..	21	58	50	26

Segregation for time of commencement of flowering complicated matters. The Spot on the first few flowers produced on a plant never fully develops its colour.

Hairs on Petiole.
Valencia .. .. Many.
Sine .. .. Few.

The frequency array is contained in Table 7. The complete absence of hairs on the petioles of three plants is interesting, but no conclusions regarding inheritance can be drawn.

Red colour on Main Vein at base of Leaflet.
Valencia .. .. Present.
Sine .. .. Absent.

Colour Grade .. Absent.	*Slight.*	*Present.*	*P.P.*
Number of Plants 31	43	80	4

Present is dominant over Absent (P.P.=more colour than on Valencia).

Colour of Peduncle.
Valencia .. Pale green, sometimes with a slight flush.
Sine .. Dark green.

Thirty-eight plants out of 158 had a red colouration to a marked degree on the petiole; others had it to a lesser degree. Fluctuation

among flowers of the same plant was considerable. Both pale and dark green peduncles were reproduced, but in many cases the red colour masked the green.

Indentation of Seed.

Valencia	.. 10 per cent. of total seeds are indented; those not indented include all three and four kernelled seeds.
Sine	.. Not indented.

There was much variation among seeds of the same plant; some plants, however, had definitely more indented seeds than Valencia.

Leaf Index.

Valencia	..	..	2.4
Sine	..	..	1.9

(*See Table at bottom of page.*)

Sine type of leaf is dominant over the Valencia type.

Seed Shape.

Valencia	.. About five per cent. of seeds are curved or hump-backed.
Sine	.. Seeds straight.

Sixty-eight plants out of 146 had a high proportion (about 60 per cent.) of curved seeds.

Number of leaflets.

Valencia	..	...	4
Sine	..	...	4

Twenty plants out of 158 had a high proportion of leaves with five leaflets, instead of the usual four. There was no clean-cut segregation, the character grading from plants with nearly all leaves having five leaflets, to those with only one or two leaves with five leaflets. The fifth leaflet varied in position and size between plants. (*See* illustrations.)

Length of Leaf.

Valencia	..	..	60
Sine	..	..	35

The length in some cases segregated into values higher or lower than those of either of the parents. The frequency array is in Table 1.

Length of Sheath.

Valencia	..	..	30
Sine	..	..	20

The frequency array is shown in Table 2. The sheath length in 14 cases exceeded that of Valencia, and it is interesting to note that the length in five cases was as low as 2 mm.; the latter have been included in the 5 mm. class for convenience.

V. Correlations.

The possibilities of correlations of all characters with each other were examined. While some of them showed linkage or correlation, none of the characters that gave clean-cut segregation showed any connection with each other. Thus it is impossible at the present stage to state whether they are linked or correlated, or the number of units they are apart.

The following group of eight characters all showed well-marked lineage or correlation with each other. (For examples *see* Tables 1 to 7.)

Length of leaves.	Width of leaves.
Length of petiole.	Corolla colour.
Length of rachis.	Hairs on petiole.
Length of sheath.	Number of seeds.

The group contains all the vegetative characters examined, so that it may merely be the large size of leaf, &c., contributing to the general vigour of the plant, which influenced the yield. The relation between number of seeds and hairs on petiole is more important, and may be of immediate use in selecting or breeding for high yielding qualities.

The freshness of the flowers is connected with yield (*see* Table 8) but while plants with fresh, intermediate and faded flowers gave mean decreasing yields in the same order, some of the highest yielders were in the faded and intermediate classes; an early fading flower, however, may fade before the pollen tubes have completed their growth, which would partly account for the high proportion of steriles and low yielders in these classes.

VI. Rosette Disease.

This disease causes great reductions in yield in many parts of Africa (9), and the possibility of obtaining an immune type was kept in mind. The varieties listed earlier in the paper are as complete a collection of forms of *Arachis hypogea* as it has been possible to obtain up to the present, and all have been found to be susceptible in some degree to the attack of Rosette disease. Further, specimens of a different species, *A. nambyquarae*, which it had been hoped might be useful in introducing immunity, were found in 1931 to be susceptible. The prospects of evolving an immune type are therefore unpromising. Nevertheless, the F_2 was tested for immunity or resistance by bottle-grafting (8) a diseased branch on to each member. This method was previously found to give a very high percentage of grafts, and where the graft has caught Rosette is invariably transmitted, except near the end of the growth period. Nearly 50 per cent. of the segregates became infected with Rosette; probably more would have been infected if the grafting had been carried out earlier in the season. Any immune types will be discovered in later generations.

Leaf Index	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9
No. of Plants....	1	1	1	4	5	3	5	11	13	17	19	18	22	9	13	5	2	6	1	2

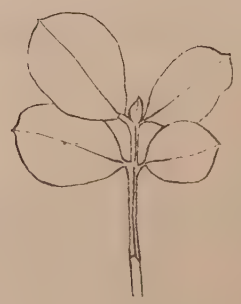
THE CLASSIFICATION OF GROUNDNUT VARIETIES.

New leaf forms appearing in the F_2 generation of a groundnut cross (Valencia × Sine)

Rudimentary rachis and a fifth leaflet present of almost the same size as the others.

The normal number of leaflets but rachis absent. Abnormally deep groove in petiole.

A fifth smaller leaflet present and rachis absent.



A fifth smaller leaflet present and leaf sheaf rudimentary.

VII. Summary.

(1) A number of flower, vegetative and seed characters of the Groundnut are examined in detail, and by this means 35 varieties are classified in four Bunch and six Runner groups.

(2) These characters are examined in the analysis of the F_2 generation of a Valencia × Sine cross. The following information on the inheritance of characters is obtained :—

Dominant.	Recessive.	Ratio.
Red brown testa	Light brown testa	3 : 1
Much red colour on stem	Slight red colour on stem	3 : 1
Runner habit	Bunch habit	15 : 1
Long seed	Short seed	15 : 1
Flowers fading early	Flowers fading late	—
Deep coloured corolla	Light coloured corolla	—
Red colour on leaflet vein	Absent	—
Sine leaf shape	Valencia leaf shape	—
Governed by Complementary Factors.		
Fertile	Sterile	15 : 1
Normal leaf	Crinkled leaf	15 : 1
Rachis present	Rachis absent	15 : 1

(3) No characters that exhibit clean-cut segregation show any connection with one another.

(4) Eight characters, five of which are vegetative, are found to be connected with yield.

(5) A search for a type immune to Rosette disease gave inconclusive results.

Acknowledgments.

The writer is indebted to Professor E. E. Cheesman for valuable suggestions and criticisms on the work. The method of establishing a series of grades and of having standard plants for each grade is that employed by Dr. S. C. Harland at the Cotton Research Station, Trinidad. Acknowledgment is also due to the Director of Agriculture, The Gambia, for permission to publish this paper.

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VIII. Appendix.

TABLE 1.

LENGTH OF LEAVES AND WIDTH OF LEAVES.

Width in mm.	Length in mm. 10	15	20	25	30	35	40	45	50	55	60	65	70	75	Total.	Mean.
10	1	2	....	....	....	....	....	....	....	....	....	....	....	....	3	13.3
15	....	....	1	2	2	1	....	2	....	....	....	....	....	....	8	31.8
20	....	....	1	3	1	3	11	14	10	3	3	....	....	....	49	43.7
25	....	....	....	....	....	2	5	13	16	13	13	2	1	....	65	51.5
30	....	....	....	....	....	....	2	....	9	8	3	5	3	....	30	56.1
35	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1	50
40	....	....	....	....	....	....	....	1	....	....	....	....	....	1	2	60
Total	1	2	2	5	3	6	18	30	36	24	19	7	4	1		

TABLE 2.

LENGTH OF LEAVES AND LENGTH OF SHEATH.

Length of sheath.	Length of leaves. 10	15	20	25	30	35	40	45	50	55	60	65	70	75	Total	Mean.
5	1	2	1	3	2	....	....	3	....	....	....	....	....	....	12	27.5
10	....	....	1	2	1	....	5	....	....	....	....	....	....	....	9	33.3
15	....	....	....	....	....	5	2	4	....	....	....	....	....	....	11	39.5
20	....	....	....	....	....	1	5	9	10	2	1	....	....	....	28	46.7
25	....	....	....	....	....	....	6	10	9	12	6	1	2	....	46	52.5
30	....	....	....	....	....	....	....	3	15	9	10	3	2	....	42	55.1
35	....	....	....	....	....	....	....	1	....	1	2	2	....	....	6	58.3
40	....	....	....	....	....	....	....	....	2	....	....	1	....	1	4	60.0
Total	1	2	2	5	3	6	18	30	36	24	19	7	4	1		

TABLE 3.

LENGTH OF LEAVES AND LENGTH OF PETIOLE.

Length of petiole.	Length of leaves. 10	15	20	25	30	35	40	45	50	55	60	65	70	75	Total.	Mean.
10	1	....	....	....	....	....	....	....	....	....	....	....	....	....	1	10.0
15	....	....	....	1	....	....	....	....	....	....	....	....	....	....	1	25.0
20	....	2	1	2	1	....	....	1	....	....	....	....	....	....	7	22.9
25	....	....	1	1	....	3	1	2	....	....	1	....	....	....	9	37.7
30	....	....	....	1	1	3	3	4	1	1	....	....	....	....	14	40.3
35	....	....	....	....	....	....	6	8	10	2	....	....	....	....	26	46.5
40	....	....	....	....	1	....	6	11	9	7	4	....	2	....	40	49.5
45	....	....	....	....	....	....	2	2	7	8	6	1	....	....	26	53.3
50	....	....	....	....	....	....	....	1	5	4	5	3	1	....	19	56.8
55	....	....	....	....	....	....	....	1	3	....	2	2	1	1	10	59.0
60	....	....	....	....	....	....	....	....	1	2	1	1	....	....	5	57.0
Total	1	2	2	5	3	6	18	30	36	24	19	7	4	1		

TABLE 4.

LENGTH OF LEAVES AND LENGTH OF RACHIS.

Length of rachis.	Length of leaves. 10	15	20	25	30	35	40	45	50	55	60	65	70	75	Total.	Mean.
0		1				1		2	1						5	29.0
1																0
2	1														1	10.0
3																0
4																0
5				1											1	25.0
6		1		1				1							3	28.3
7					1	2	4	2			1				10	41.0
8			1		1			1		1					4	37.5
9			1	3		2	1	1	4	4					16	41.9
10					1		7	10	9	3	2				32	46.7
11						1	2	4	6		2				15	47.7
12							1	5	7	3	1	1			18	50.3
13							3	1	4	7	4	2	1		22	54.1
14								1	1	1	3		1		7	57.1
15								2	3	3	3	2	1		14	56.1
16												1	1		2	67.5
17									1	1	2			1	5	60.0
18											1	1			2	62.5
19										1					1	55.0
Total	1	2	2	5	3	6	18	30	36	24	19	7	4	1		

TABLE 6.

LENGTH OF LEAVES AND COROLLA COLOUR.

Corolla colour.	Length of leaves. 10	15	20	25	30	35	40	45	50	55	60	65	70	75	Total.	Mean.
2							3	3	7	6	3	1	1		24	52.1
3				2	1	3	8	11	15	8	11	1	3	1	64	50.0
4		1	2	3	2	2	3	14	13	10	5	5			60	47.3
5		1				1	3	1	1						7	37.8
Total		2	2	5	3	6	17	29	36	24	19	7	4	1		

TABLE 5.

LENGTH OF LEAVES AND NUMBER OF SEEDS.

Length of leaves	Number of seeds. 0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	135	Total.	Mean.
10	1																								1	0
15	2																								2	0
20	1				1																				2	12.5
25			2			1		2																	5	23.0
30			1	2																					3	13.3
35	2	1		1		1		1																	6	13.3
40	1	3		3	2	3	1	2	1			1											1		18	26.6
45	1	6	6	2	4	3	3			1		2	1											1	30	23.8
50	3	4	1	2	5	4	2	2	2	3	2	2	1	1					1	1					36	31.2
55		4	2	3		2	1	3	1	2	2	1		1		1				1					24	32.9
60	1	3	3	1	2	1	1	1	1			1	1		1	1					1				19	31.0
65		2			1		1	2			1														7	25.7
70			1						1						1	1									4	48.8
75												1													1	55.0
Total	12	23	16	14	14	16	9	13	6	6	5	8	3	2	2	3			1	2	1		1	1		

TABLE 7.

LENGTH OF LEAVES AND HAIRS ON PETIOLE.

Hairs on petiole.	Length of leaves. 10	15	20	25	30	35	40	45	50	55	60	65	70	75	Total.	Mean.
None	1	1	....	....	....	....	....	....	1	....	....	....	....	....	3	25.0
Few	....	....	1	1	2	2	2	6	....	....	1	....	....	....	15	39.0
Few	....	....	1	....	1	....	....	5	6	6	7	4	2	2	....	34	50.1
Medium	....	....	....	1	3	1	4	7	7	13	11	6	....	2	....	55	47.5
Many	....	....	....	....	....	....	....	4	11	10	6	8	5	....	1	51	52.2
Total	1	2	2	5	3	6	18	30	36	24	19	7	4	1			

TABLE 8.

NUMBER OF SEEDS AND FRESHNESS OF FLOWERS.

Freshness of flowers.	Number of seeds. 0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	135	Total.	Mean.
Fresh	....	2	....	1	1	1	1	1	1	....	....	1	....	....	....	....	....	....	....	1	....	....	....	....	10	32.5
Intermediate	4	12	8	10	6	10	6	4	4	5	3	5	2	1	2	3	....	....	....	1	1	....	1	....	88	30.1
Faded	5	9	8	3	7	5	2	8	1	1	2	2	1	1	....	....	....	....	1	....	....	....	....	1	56	25.4
Total	9	23	16	14	14	16	9	13	6	6	5	8	3	2	2	3	....	....	1	2	1	....	1	1		

TABLE 9.

NUMBER OF SEEDS AND HAIRS ON PETIOLE.

Hairs on petiole.	Number of seeds. 0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	135	Total.	Mean.
None	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3	0
Very Few	3	2	4	2	....	1	2	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	15	13.3
Few	2	5	2	4	2	2	4	3	3	1	2	1	1	....	....	2	....	....	....	....	....	....	....	....	34	27.9
Medium	4	7	6	5	5	8	1	5	1	3	2	3	1	1	2	....	....	....	....	1	....	....	....	....	55	26.8
Many	....	9	4	3	7	5	2	4	2	2	1	4	1	1	....	1	....	....	1	1	1	....	1	1	51	34.6
Total	12	23	16	14	14	16	9	13	6	6	5	8	3	2	2	3	....	....	1	2	1	....	1	1		

PAPAW ROOT AND COLLAR-ROT.

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Introduction.

A foot-rot and root-rot of the papaw (*Carica papaya*, Linn.) was recorded for the first time from Trinidad by Stevenson (2) in 1931. Papaw foot-rots and wilts which may or may not be identical with the one under discussion have been described from various other countries. Subramaniam (3) described a foot-rot of the papaw in India, said to be caused by *Pythium Butleri*; Abbott (1) recorded a wilt constantly associated with a species of Fusarium in Peru; and Wager (4) described a foot-rot in South Africa, which he attributed to *Pythium ultimum*. Stevenson (2) considered that of these three, the South African disease alone was almost certainly identical with the one he found in Trinidad.

Stevenson (2) described the foot-rot, or collar-rot, as a sudden wilting of the tree as though the trunk had been severed, this being occasioned by a rotten area at the base of the trunk. In the case of the root-rot, death was less rapid, being characterised by a slowing down of growth and a decrease in number and size of the leaves, with a final reduction of the crown to a tuft of yellowish leaves a few inches across. When this stage had been reached, secondary fungi and bacteria rapidly destroyed the whole tree. He found that the taproots of such trees were brown and rotten and that many of their lateral roots showed a similar discolouration.

On making isolations from junctions between diseased and healthy tissue he obtained, amongst other fungi of an obviously secondary nature, a species of Fusarium and a species of Pythium. On making inoculations with these two fungi, in his first series he obtained no results with the Pythium species, but found that it was possible, though difficult, to produce typical root-rot and collar-rot symptoms with the Fusarium. A second series of inoculations, however, gave precisely the opposite result, the plants inoculated with the Pythium dying in about one month, while those inoculated with the Fusarium remained healthy. All his successful inoculations were obtained by inserting mycelium from cultures of the fungi into wounds in the stems or roots of papaws growing in tins.

During the year 1932-33 no trace of the disease in either form has been seen in the plantation; but experiments have been carried out in the laboratory to settle the question of the pathogenicity of these two fungi. Single spore isolations were made from Stevenson's cultures and only cultures derived from these single spores were used in the inoculation experiments.

An account of these experiments follows :—

Inoculation Experiments.

All inoculations were carried out on papaw seedlings from one to two feet in height growing in soil in kerosene tins, two plants per tin. All plants were kept on the roof of the College building.

The technique used in making the inoculations was as follows. A wound was made in the cortex of the stem with a sterile scalpel and a piece of potato-sucrose-agar medium bearing mycelium and spores was placed in the wound. This was then moistened with a drop of sterile water, bound up with paper and tied with cotton, then sealed with vaseline. Controls were made in an exactly similar manner except that the piece of potato-sucrose-agar medium placed in the wound was sterile. When roots were inoculated the technique used was simpler; a wound was made in the root, the inoculum inserted, moistened with a drop of sterile water, and carefully covered up again with soil.

In all the experiments the control plants were prepared before the inoculations were made.

Experiment I.

Plants nine inches to one foot high.

Wounds in stem about one inch above soil level.

Series Number.	Inoculum.	Number Inoculated.	Number Diseased.	Time to death of plant.
				Days.
1	Fusarium ..	6	2	17-23
2	Pythium ..	6	1	17
3	Control ..	6	—	—
4	Fusarium v. young mycelium	6	1	19
5	Pythium v. young mycelium	6	1	21
6	Control ..	6	—	—

Successful re-isolations were made from Series 1 and 2.

Experiment II.

Plants one to two feet high.

Wounds in stem about one inch above soil level.

Series Number.	Inoculum.	Number Inoculated.	Number Diseased.	Time to death of plant.
				Days.
1	Fusarium ..	6	3	14-21
2	Pythium ..	6	—	—
3	Control ..	6	—	—

Successful re-isolations were made from Series 1.

EXPERIMENT III.

Plants about one foot high.

Wounds made in lateral roots about an inch below the soil level and about an inch from the taproot.

Series Number.	Inoculum.	Number Inoculated.	Number Diseased.
1	Fusarium ..	6	—
2	Pythium ..	6	—
3	Control ..	6	—

Complete negative result.

EXPERIMENT IV.

Plants one to two feet high.

Wounds in stem about two inches above soil level.

Series Number.	Inoculum.	Number Inoculated.	Number Diseased.	Time to death of plant.
				Days.
1	Fusarium ..	6	5	12-25
2	Pythium ..	6	6	15-23
3	Control ..	6	1	33

Successful re-isolations were made from Series 1 and 2.

A dark green mycelium, probably that of *Botryodiplodia theobromae*, a common wound parasite of the papaw, was obtained from the dead control.

EXPERIMENT V.

Plants one to two feet high.

Wounds in taproot about two inches below soil level.

Series Number.	Inoculum.	Number Inoculated.	Number Diseased.	Time to death of plant.
				Days.
1	Fusarium ..	6	—	—
2	Pythium ..	6	1	8
3	Control ..	6	—	—

Taking these results together, the Fusarium in a stem wound killed eleven out of twenty-four, and the Pythium in a stem wound killed eight out of twenty-four plants inoculated. In the case of root inoculations, the Fusarium killed none out of twelve and the Pythium one out of twelve. Of the thirty-six controls, all except one remained healthy.

Discussion.

It is seen from these experiments that both fungi are capable of causing a stem-rot of the papaw, but that little success has been obtained in inoculating roots. Infection can only be brought about with difficulty under experimental conditions, and it seems to be essential for both organisms to have a very moist atmosphere to start growth. This was obtained by means of paper and vaseline under the conditions of the experiment. It appears to be even more difficult to infect the roots than the stems.

The conclusion is that both these organisms are capable of attacking and killing the papaw, given suitable conditions. Probably both are able to live saprophytically in the soil and were enabled to attack the papaws in the plantation because conditions became exceedingly favourable for their growth. The year in which Stevenson (2) reported most damage was abnormally wet and there was a heavy cover crop on the field around the papaws. These two factors would tend to produce an unusually high humidity around the bases of the trees suitable for the rapid growth of the organisms in question. During the past year there has been a better dry season and the ground around the bases of the trees has been kept clear of weeds. No cases of root or collar-rot have been found.

When the plantation was replanted at the beginning of the year the young plants were put as far as possible in the positions which their predecessors had occupied. Since many of the trees in the old plantation died of root or collar-rot the soil must have been heavily contaminated with these two organisms and it was expected that they would kill some of the young plants. This did not occur and it is assumed that conditions must have been unsuitable for the fungi. In a normal season special control measures seem to be unnecessary, but during abnormally wet spells it would be advantageous to bare the ground around the bases of the trees, and to pay attention to drainage. No other precautions appear to be necessary.

Acknowledgment.

The author wishes to thank Dr. H. R. Briton-Jones for his useful help and advice throughout the course of the work.

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THE RELATIONSHIP BETWEEN DEGREE BRIX (HYDROMETER) AND DEGREE BRIX (REFRACTOMETER) IN FINAL MOLASSES—II.

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IT has previously been demonstrated (1) that a regression equation may be calculated showing the relationship between Degree Brix (Hydrometer) and Degree Brix (Refractometer). Two methods were put forward on which such equations may be based: (1) The direct relationship between degree brix (Hydrometer) and degree brix (Refractometer), and (2) the relationship between the hydrometer and refractive non-sugars. The former is the simpler of the two, involving nothing more than a hydrometer reading, and, if anything, yields the more accurate results. Further data has now accumulated, and an opportunity thus presents itself to show whether an equation established on the results of one crop is effective in predicting the relationship during another crop. Two of the factories which collected weekly composite samples of Final Molasses for the previous work have continued to collect a similar series during the last two crop periods. Degree Brix (Hydrometer) and Degree Brix (Refractometer) have been determined in the laboratory by the same methods as before. The Degree Brix (Refractometer) has also been calculated, using the regression equation previously established, and the results compared with the determined value.

Table I shows some typical predicted values of Degree Brix (Refractometer), together with the determined value and the Degree Brix (Hydrometer) from which the predicted value was calculated.

Table I.

Sample No.	°Bx. (Hyd.)	°Bx. (Ref.)	Predicted °Bx. (Ref.)	Difference.
Factory A.				
12/32	85.6	81.2	80.9	−0.3
17/32	84.6	80.7	80.0	−0.7
4/33	86.0	80.8	81.3	+0.5
14/33	86.9	82.0	82.1	+0.1
Factory C.				
7/32	81.0	77.4	77.7	+0.3
9/33	88.8	83.6	83.1	−0.5
17/33	88.4	82.8	82.8	0.0

Factory A.—°Brix (Refract.) = 2.3 (0.9188 × °Bx. (Hyd.).)
Factory C.—°Brix (Refract.) = 21.3 (0.6965 × °Bx. (Hyd.).)

The differences between the predicted values for degree Brix (Refractometer) and the determined values for each of the two factories are shown in Tables IIA and IIB.

Table IIa.

Differences between Predicted and Determined Values of °Bx. (Ref.)

FACTORY A.

Differences.	No. Samples.	Percentage.
0.0 -0.20	11	26.8
0.21-0.40	9	22.0
0.41-0.60	7	17.1
0.61-0.80	9	22.0
0.81-1.00	3	7.3
Above 1.00	2	4.8
Total ..	41	100.0

Table IIb.

FACTORY C.

Differences.	No. Samples.	Percentage.
0.0 -0.2	12	41.4
0.21-0.4	9	31.0
0.41-0.6	4	13.8
0.61-0.8	2	6.9
0.81-1.0	2	6.9
Above 1.0	0	0.0
Total ..	29	100.0

Factory A shows a rather wider distribution of differences than Factory C, but in both cases the means of the predicted and determined values agree to an extent which would produce very small errors under conditions of factory use. See Table III.

Table III.

COMPARISON OF MEANS.

No. Samples.		Actual °Brix (Refract.).	Predicted °Brix (Refract.).
Factory A.	41	80.95	81.30
Factory C.	29	80.86	80.96

It therefore appears that a regression equation showing the relationship between degree Brix (Hydrometer) and degree Brix (Refractometer) holds good for any one factory from one crop to the next, since five crop series of samples are

1. Davies, J. G. *Trop. Agriculture* (1932), 9, 218.

included in the Factory A data and three crop series of samples are included in Factory C data. Furthermore, the Factory C equation was established on data which only covered one crop period. Hence the cause of the differences between the two methods of estimating total solids apparently remains constant from year to year, and is characteristic of the factory, so that when once a regression equation has been established, it may be used with reasonable security against error during subsequent crop periods.

CHEMICAL NOTES.

Compiled by the College Department of Chemistry and Soil Science.

A New Use for Rubber.

A new rubber-base product, with the name "Plioform", has recently been announced by the Goodyear Tyre & Rubber Co. of America. It is stated that this material is entirely suitable for table-ware, as it is tasteless and odourless, is resistant to scratches, and is unbreakable. It is manufactured from pale crêpe rubber, which is dissolved in a solvent and chemically treated to give a white resinous compound, which can be moulded to give articles of a light amber colour, or mixed with a filler and pigment and milled. The material also possesses good non-conductive properties, which makes it suitable for moulded electrical parts.—(*Chem. and Ind.*, Vol. 52, 1933, No.13, p. 293).

* * *

Injurious effects of Manganese and Iron deficiencies on the growth of Citrus. *A. R. C. Haas, Hilgardia.* VII. 4. 1932.

The material used was rooted cuttings of rough lemon, lemon (*Citrus Limonia*) and orange (C. *sinensis*) grown in culture solutions in shallow enamelled pans for a year or more. Budded trees in large sand cultures were also used. Among conclusions reached are the following:—Manganese is necessary for healthy growth of citrus cuttings in culture solutions. As the result of manganese deficiency the leaves become yellowish-green or chlorotic but do not mottle. Gum or resinous spot occurs on either or both sides of the leaves. Oil glands in the leaves are not affected. Manganese deficient leaves in acute stages fall prematurely and the shoots die back. The roots remain healthy in appearance. Excessive manganese concentrations also cause chlorosis, even though iron is added to the culture solution in similarly large amounts. Iron is also essential and its deficiency causes chlorosis. When manganese is deficient, the accumulation of iron in the leaves is generally less. Mottle leaf has not been shown to be due to iron deficiency. Neither manganese nor iron can replace one another. In any study of manganese deficiency it must be remembered that most compounds of iron contain manganese as an impurity. —(*Horticultural Abstracts*, Vol. III. No. 2. Ab., 218.)

Effect of Weed-Killers on the Soil.

A question of importance in the use of chemicals for weed eradication is the possibility of such compounds exerting a deleterious effect on the soil, with risk of injury to the subsequent crop. Some investigations on these lines have been carried out by W. E. Bowser and J. D. Newton (*Canadian J. Research*, **8**, 73). The liability of damage depends in part at least on the rate of decomposition of the chemical, its rate of movement in the soil, and its effect on microbiological activity. Sulphuric acid and copper sulphate, which are employed chiefly as leaf sprays for the suppression of annual weeds, showed no lethal effect on the soil, and nitrification was not affected. Sodium chlorate, on the other hand, which is mainly used for the eradication of perennials, remained undecomposed for a considerable time, poisonous effects being found nearly two years after application had been made. The rate of decomposition, however, was accelerated in the presence of much organic matter, and leaching removed the toxic compound from the surface layers of the soil, facts which suggest that a shallow rooted crop supplied with a good dressing of organic manure would be advisable after a sodium chlorate treatment. Sodium bichromate decomposed rapidly, showing no residual toxic effects, but both this compound and sodium chlorate were alike in exerting a depressing influence on the numbers of soil micro-organisms. (*Nature*, Vol. 131, 1933, p. 880.)

* * *

World Production of Artificial Silk.

According to figures published in *Die Chemische Industrie* (March 11th, 1933), the world production of artificial silk in 1932 was 232,800 metric tons, compared with 140,000 tons in 1927 and 35,000 tons in 1932. The 1932 output represents 80 per cent. of the capacity of the existing plant. The chief producers were: United States—59,300 tons; England—32,900 tons; Italy—32,100 tons; Japan—29,200 tons; Germany—28,000 tons; and France—21,000 tons. Production in England and Japan showed a very considerable increase compared with 1931, but in Germany and the United States there was a decline. Over 80 per cent. of the 1932 output was by the viscose process.—(*Chem. and Ind.*, Vol. 52, 1933, No. 20, p. 437.)

TREND OF THE MARKETS.

[*The notes below are based principally upon running charts of the prices of the basic grades and upon general statistical information gleaned from contemporary publications and cablegrams and are intended to be a record of movements. An attempt is made, where possible, to indicate the market outlook at the time of going to press, but no responsibility for the accuracy and subsequent truth of such observations is assumed. Unless otherwise stated the prices quoted are spot, London.*]

SUGAR.—Prices on the Home Market have ranged as follows (c.i.f. per cwt.) :—

	Foreign.		*Preferential.*	
	s.	*d.*	*s.*	*d.*
31st August ..	5	1½	9	10½
7th September ..	5	6¾	10	10¾
14th September ..	5	4½	10	1½
21st September ..	5	3	10	0
28th September ..	5	0¾	9	9¾
5th October ..	4	11¼	9	9¾
12th October ..	4	11¼	9	10½
(13*th Oct.*, 1932) ..	6	0	10	8¼

After showing considerable strength the market has gradually lost ground. The uncertainties surrounding the near future have caused some nervousness while it is anticipated that news from Cuba will be an unsettling factor until more stable conditions prevail. The proposed allotment scheme for sugar supplies in the United States has been abandoned. In Java the current export is under 1½ million tons while this year's plantings are at present calculated to yield barely ½ million tons next year.

* * *

COFFEE.—A very high price has been paid for Jamaica, 210*s.* and 218*s.*, 220*s.* up to 237*s.* Other sales include Costa Rica 125*s.* and 97*s.*, Kenya 75*s.* and 55*s.*, Santos 43*s.*

* * *

RUBBER.—Quotations for Plantation Sheet have ranged as follows :—

	d.
30th August	3¾
6th September	3 11/16
13th September	3 19/32
20th September	3 13/16
27th September	3 29/32
4th October	4
11th October	4 1/32
(12*th Oct.*, 1932)	2 7/16

After being somewhat quiet early in September, the market was very much firmer during the latter part of the month, prices showing considerable advance. The actual upward movement is stated to have started with the passing by the People's Council in the Dutch East Indies of a Bill for the emergency regulation of exports. Other contributory factors include the American inflatory movement which has brought with it improvement in commodity prices and the publication of the American Questionnaire figures which were fully up to expectations.

COCOA.—Since last writing the market continues with a very dull tone and shippers are now showing more desire to sell new crop Gold Coast Cocoa—Accra—and on a firm bid one could doubtless buy at 21*s.* 6*d.* c.i.f. Continent. Locally the market shows no improvement and plantation cocoa is offered at $5.00 a fanega.—(*By courtesy of The Cocoa Planters' Association of Trinidad, Limited.*)

* * *

COTTON.—The following are the official spot prices in pence per lb. of the Liverpool Cotton Association :—

	American Mid.	*Egyptian F.G.F. Sakel.*
25th August ..	5.53	7.52
1st September ..	5.60	7.53
8th September ..	5.38	7.25
15th September ..	5.47	7.30
22nd September ..	5.42	—
29th September ..	5.59	—
6th October ..	5.49	—
13th October ..	5.37	—
(14*th Oct.*, 1932) ..	5.43	7.97

The market has generally been quiet, the outlook being rather confusing and indefinite. The indicated crop according to the latest Bureau Report is 12,414,000 bales. Very little West Indian Sea Island has been sold, the price realised being 12*d.* per lb.

* * *

BANANAS.—There has been a slightly better demand for Jamaicas, and the price, per ton, is unchanged at :—

	Delivered London.	*Provinces nearest Station.*
Jamaica Producers ..	£20 5	£20 0
Elders & Fyffes ..	17 15	17 10

A fair business is passing in Brazilians at £19 per ton delivered nearest station.—(*West India Committee Circular*, 14th September.)

* * *

COPRA :—The demand is poor and values are lower. West Indian f.m.s. has declined to £10 12*s.* 6*d.* c.i.f. October shipment.—(*West India Committee Circular*, 14*th* September.)

* * *

LIME PRODUCTS. *Lime Oil.*—Handpressed is again easier with sellers at 42*s.* 6*d.* per lb. Distilled is inactive and unchanged at 29*s.* 6d. spot. *Lime Juice.* — There are buyers of Concentrated at £4 10*s.* The freight rate has been reduced from 4½*d.* to 3½*d.* per gallon, in view of the low price obtainable. Raw is quiet but steady at 2*s.* 3*d.* to 2*s.* 6*d.* for good to fine Jamaica. (*West India Committee Circular*, 14th September.)